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THE U. S. S. *TACOMA.*

GENERAL DESCRIPTION.—OFFICIAL TRIAL.

BY LIEUTENANT U. T. HOLMES, U. S. N., MEMBER.

The *Tacoma* is one of the six sheathed protected cruisers authorized by the Act of Congress approved March 3, 1899, the other vessels of this class being the *Denver, Des Moines, Chattanooga, Galveston* and *Cleveland.* The *Tacoma* was contracted for by the Union Iron Works, San Francisco, Cal., December 14, 1899, the price being $1,041,900, and the time for delivery thirty months from date of contract.

The keel was laid September 27, 1900, and the vessel was launched June 2, 1903, much delay having been caused by a strike of workmen at the works of the contractors lasting from May, 1901, to March, 1902. Before launching, the hull had been sheathed with teak and coppered, and the machinery and boilers had been placed on board.

The speed guaranteed was sixteen and one-half knots, to be maintained for four hours, with an average pressure in the ash pits not exceeding one inch of water. A penalty was to be exacted in case the contract speed was not obtained.

HULL DATA.

Length between perpendiculars, feet	292
over all, feet and inches	308- 6
Beam, extreme, feet and inches	44- 1½
at L. W. L., feet	44
Depth, molded, upper deck, feet and inches	30- 2¾
Draught, normal, feet and inches	15-10
Displacement at mean normal draught, tons	3,200
Tons per inch at L. W. L	22.4
Area immersed midship section to L. W. L., square feet	614
Center of gravity of L. W. L., abaft midship section, feet	3.8
buoyancy above bottom of keel, feet	9.18
abaft midship section, feet	1.41
gravity above bottom of keel	
Metacentric height, transverse	
longitudinal	
Coefficient of fineness, block	.554
M. S	.878
L. W. L	.733
Cylinder coefficient	.628
Number of frames spaced 3 feet apart	98
watertight compartments	206

Rig.—There are two light masts for signal purposes, each provided with two fore-and-aft booms for hoisting in stores. Two additional booms on each side are provided for use in coaling, these stepping in heels on the boat davits.

Upper Deck.—The upper deck is flush fore and aft, and contains the chart house and pilot house, the latter being fitted up as a sea state room for the commanding officer. The bridge is immediately over the chart house, and a platform above the bridge carries the two 30-inch searchlights. A platform immediately abaft the engine-room hatch carries the standard compass. There is a steam capstan engine forward for warping and for catting the anchor, and two 25-horsepower electric winches for hoisting in boats and stores and for coaling.

Gun Deck.—This deck contains the commanding, executive, and navigating officers' quarters and offices, the armory, officers' and crew's galleys, sick bay, dispensary, engineer and pay officers' offices, petty officers' and crew's water closets, crew's lavatory, and steam windlass; besides space for berthing and messing the greater part of the crew.

Berth Deck.—Has space for berthing and messing the remainder of the crew, and contains the ward-room officers' and warrant officers' quarters and toilet rooms, drying room, forced-draft blowers, workshop, ice machine, and refrigerating room, petty officers' and firemen's lavatories, commissary store, prison, and the electric blowers for berth deck ventilation.

Protective Deck.—Is of the usual form and extends from stem to stern. The flat portion is of 12½-pound plating. The slopes in the wake of engines, boilers and ammunition spaces consist first of 20-pound plating worked over beams and 80-pound nickel-steel plating worked over this. The slopes at ends of the ship consist of two courses of 20-pound plating. The protective deck amidships is coincident with the berth deck. The space between the slopes of the protective deck and the berth deck, forward and aft of the coal bunkers, is utilized for stores. Cofferdams, 27 inches in depth at ship's side, extend from frame No. 7 to stern between protective and berth decks, and are filled with corn-pith cellulose.

Platform Deck.—Abaft the machinery space contains storerooms and the steam steering engine. Forward of the boiler space contains the dynamo room and other store rooms. Electric blowers for the ventilation of magazines and storerooms are on this deck.

Holds.—Contain, outside of the engine and boiler space, the magazine and shell-room compartments, the fresh-water tanks, trimming tanks, chain lockers, and stowage space for heavy articles.

Magazines.—Where adjacent to engine room and coal bunkers, the bulkheads forming the partitions are sheathed with non-conducting material to prevent overheating. A supply system of forced ventilation is provided to keep the magazines cool.

Fresh-Water Tanks.—Are four in number, with an aggregate capacity of 3,368 gallons of fresh water.

Trimming Tanks.—Have connections for flooding with sea water and for pumping out from the engine room. The forward tank has a capacity of 12.28 tons and the after tank of 26.88 tons.

Bunkers.—There are eleven bunkers below the protective deck with an aggregate capacity of 409 tons, and eight bunkers between gun and protective decks with a capacity of 273 tons. The lower bunkers are coaled in the usual manner through permanent chutes passing through upper bunkers. Portable chutes of sectional construction are fitted for use in coaling through the upper deck. When not in use these chutes are taken down and stowed in the forward drum room on gun deck.

Trolleys are fitted in the lower bunkers to facilitate the transportation of coal to boilers, and in the upper bunkers to enable coal to be trimmed from any upper to any lower bunker on the same side. Small trimming doors, hinging in the opposite direction, are placed on the larger doors to permit removing sufficient coal to open the larger door, so that coal may be trimmed in either direction.

Double Bottoms.—There are twenty-nine compartments in the double bottom, of which two are under the forward hold, four under forward magazines and shell rooms, fourteen under boilers and bunkers, six under engine rooms, two under after magazine and one under after hold. Six compartments of the double bottom under boilers are fitted for use as reserve-feed tanks, and have a capacity of 59.5 tons of fresh water. These have connections to the fresh-water pumps only.

Drainage System.—The main drain is 10 inches, and the auxiliary drain 5 inches in diameter. They extend throughout the engine and boiler spaces with connections through manifolds to double bottoms and hold compartments. They have connections for flooding from sea and for pumping out, as noted for the various pumps. The main and the more important auxiliary drain suction valves have gear for opening from deck. Besides the connections to steam pumps the drainage manifolds have connections to the hand pumps on deck.

Ground Tackle.—All anchors are of the regular Navy pattern except the port bower, which is a Dunn patent anchor. The two bowers and the sheet anchor are all 6,000-pound anchors. There are two stream anchors, one weighing 2,000 and the other

1,500 pounds, and two kedges, one weighing 750 and the other 400 pounds.

There are three chain lockers for bower and sheet chain. The chain is $1\frac{3}{4}$ inches diameter. Two reels of $4\frac{1}{2}$-inch steel wire hawser, containing 100 fathoms each, are placed on the upper deck.

Boats.—

One 30-foot steam launch.
One 30-foot sailing launch.
Four 28-foot 10-oared cutters.
One 28-foot whaleboat.
One 28-foot gig whaleboat.
One 20-foot dinghy.
One 16-foot dinghy.

The steam launch, sailing launch and two of the cutters stow in cradles on boat booms. The two dinghies stow in the sailing launch and one of the cutters. The remaining two cutters and the whaleboats secure at davits. Davits are provided for hoisting the two dinghies in port.

Armament.—

Ten 5-inch 50-caliber guns, Mark V, mounted on pedestal mounts, Mark IX.
Eight 6-pounder Maxim-Nordenfeld, semi-automatic, Mark II.
Two 1-pounder Hotchkiss, Mark II.
Four Colt automatic, .30 caliber.
One 3-inch field gun.

Two of the 5-inch guns are mounted amidships on the upper deck, one forward and the other aft. Eight are in broadside on the gun deck. Four 6-pounders are mounted in rail sockets on the upper deck and four in broadside on the gun deck. Six 1-pounder mounts are provided, four on the rail on upper deck and one on each quarter in cabin space on gun deck. Those on gun deck will ordinarily be used with adapters for the Colt automatic guns, and those in cabin for the two 1-pounders. Tripods and field carriages are also provided for use with the Colt guns. Boat mounts which may be used for either Colt guns or 1-pounders are provided for steam launch, sailing launch, and cutters.

ELECTRIC PLANT.

The electric light and power equipment, as well as the instruments for interior communication, with the exception of searchlights and some of the controllers, have been built entirely by the contractors. The exceptions noted have been supplied by the General Electric Company.

Dynamos.—There are four 300-ampère, 80-volt, multipolar, compound-wound generators, each operated by a two-cylinder-vertical, inverted, cross-compound engine designed to run at 400 revolutions per minute. The cylinders are 8½ and 13½ inches diameter by 6 inches stroke. The switch board is so arranged that any dynamo may be used on any lighting or power circuit.

Ventilating Blowers.—There are sixteen fixed electric ventilating blowers, with shunt-wound motors, as follows :

Ship's No.	Number of poles.	Ampères at full load.	Revolutions per minute.	Cubic feet of air per minute.	Exhaust or supply.	Ventilates.
1	2	5.2	2,230	410	E.	Crew's water closets.
2	4	17.25	1,220	1,460	E.	Berth deck and store rooms.
3	4	29	1,030	2,580	E.	Berth deck and store rooms.
4	2	13.2	1,390	1,160	E.	Workshop, wash rooms and berth deck adjoining.
5	2	9.8	1,650	835	S.	Shell room and store rooms.
6	4	29	1,030	2,580	S.	Dynamo room and magazine.
7	4	29	1,030	2,580	S.	Dynamo room and magazine.
8	2	13.2	1,390	1,160	E.	Dynamo room.
9	4	46	808	4,520	S.	Starboard engine room.
10	4	46	808	4,520	S.	Port engine room.
11	2	9.8	1,650	835	E.	Officers' toilets and baths.
12	4	17.25	1,220	1,460	E.	Magazine and store rooms.
13	2	13.2	1,390	1,160	E.	Magazine and store rooms.
14	2	9.8	1,650	835	S.	Steering-engine room.
15	2	9.8	1,650	835	E.	Steering-engine room.
16	4	29	1,030	2,580	E.	Ward-room and warrant officers' quarters.

Lighting Circuits.—There are eight lighting feeders supplying seventeen mains, with a total of 388 lamps. Twenty-four

$\frac{1}{12}$-horsepower desk fans, four $\frac{1}{6}$-horsepower fans, and five $\frac{1}{3}$-horsepower portable blowers will be run from these circuits. Three hundred and sixty-three ampères will be required at full load.

Searchlights.—There are two 30-inch searchlights requiring 90 ampères at 50 volts. The voltage is reduced by rheostat in dynamo room.

Ammunition Hoists.—There are ten 28.8 ampère, series-wound, 4-pole motors for ammunition hoists, designed to run at 540 revolutions per minute. The hoists are of the usual service type.

Watertight-Door System.—There are eight vertical and seven horizontal sliding watertight doors, each of which is equipped with a 10-ampère, series-wound, 4-pole motor, running at 1,000 revolutions per minute, for opening and closing. All may be operated from the central station in chart house, or individually from either side of the door. Solenoid whistles are fitted in compartments which have these doors, to give warning when the doors are to be closed.

Winches.—The two electric winches are each fitted with a series-wound, 4-pole motor, which require 235 ampères when running at 260 revolutions, full load. There are two sets of field coils in parallel, only one of which is used for ordinary work. The additional coil has a switch for throwing it in for fast speeds or extra heavy work.

Current required.	*Ampères.*
Lighting circuits and portable fans,	363
Searchlights,	180
Ventilating blowers,	306.5
Ammunition hoists,	288
Watertight doors,	150
Winches,	470
Total,	1,757.5

Capacity of generators, 1,200.

It is expected that under no condition will more than 50 per cent. of the total possible load be placed on the plant, so that the generator capacity is more than sufficient.

INTERIOR COMMUNICATION.

There is the usual system of voice-tube and telephone communication throughout the ship, with call bells where required.

Mechanical repeating telegraphs are fitted between engine rooms and bridge, and mechanical telegraphs between engine and fire rooms. Gongs are fitted in engine rooms, with pulls on quarter deck and bridge; at ash-hoist engines, with pulls in fire rooms; and at ammunition-hoist motors, with pulls on deck.

Mechanical tell-tales on bridge show the direction of turning of the engines. In each engine room there is a dial, with pointer for each engine, to show the relative speed of rotation. Electric revolution indicators are fitted on bridge, with transmitters in shaft alleys.

Electric telegraphs of the illuminated-dial pattern are fitted for transmitting speed signals from bridge to engine rooms, for steering telegraphs from bridge to after wheel and to steering-engine room, and for helm angle indicators on bridge, at after wheel, and in steering-engine room.

Mechanical thermostats in coal bunkers, magazines, and store rooms are connected to an annunciator on gun deck aft.

General-alarm gongs are located in all compartments of the crew space and in the officers' quarters, with contact makers in chart house, commanding officer's state room, and executive officer's office.

Boat signal gongs are placed in officers' quarters, with push button on quarter deck.

DATA OF MAIN ENGINES.

Cylinders, number for each engine	4
H.P., diameter, inches	18
I.P., diameter, inches	29
F. L.P., diameter, inches	35½
A. L.P., diameter, inches	35½
stroke, inches	30
Valves, H.P. (one for each cylinder), diameter, inches	11
I.P. (two for each cylinder), diameter, inches	11
L.P. (one double-ported slide for each cylinder), inches— length, 25¾; width, 42; length of ports	38
Valve stems, H.P. (1), diameter, lower ends, inches	2

Valve stems, H.P. (1), diameter through valve, inches	1⅝
at balance piston, inches	1 3/32
I.P. (2), diameter, lower ends, inches	2
through valve, inches	1⅝
at balance piston, inches	1 3/32
L.P. (2), diameter, lower ends, inches	2½
through valve, inches	1⅝
at balance piston, inches	1 7/16
Balance pistons, H.P. (1), diameter, inches	5
I.P. (2), diameter, inches	5
L.P. (2), diameter, inches	7½
Piston rods, diameter, inches	4½
length from piston to center of crosshead pin, inches	56⅝
axial hole, diameter, inches	2
Connecting rods, center to center, inches	67
diameter, upper ends, inches	4½
diameter, lower ends, inches	4⅝
diameter, axial hole, inches	2
Main steam pipe (steel), diameter, inches	6
exhaust pipe (copper), diameter, inches	12½
Crosshead pins, diameter, inches	5½
axial hole, diameter, inches	2½
length in bearing, inches	10
Crank shaft, diameter, inches	9½
axial hole, diameter, inches	5
length (both sections), feet and inches	18– 6
coupling discs, diameter, inches	17
thickness, inches	2½
bolts in flanges (6), taper, diameter at face of coupling, inches	2
journals and crank pins, diameter, inches	9½
length, inches	11
axial hole, diameter, inches	5
Crank webs, width, inches	10½
thickness, inches	5½
Thrust shaft, diameter, inches	9½
axial hole, diameter, inches	5⅝
length, feet and inches	7– 9
collars, number, each shaft	11
diameter, inches	14
thickness, inches	1⅝
distance between, inches	3½
surface on white-metal face of horse shoes, both engines, square inches	1,168
Line shaft, diameter, inches	9
axial hole, diameter, inches	5⅝
length feet and inches	26– 0

Stern-tube shaft, diameter, inches	9
axial hole, diameter, inches	2 to $5\frac{5}{8}$
length, feet and inches	37– $0\frac{1}{2}$
Propeller shaft, diameter, inches	9
axial hole, diameter, inches	2 to $5\frac{5}{8}$
length, feet and inches	20– $0\frac{1}{2}$
Total length of shafting from forward end of crank shaft to after end of propeller shaft, feet and inches	109– 1

DETAILS OF VALVE SETTING IN FULL GEAR.

	H.P.		I.P.		L.P.	
Travel of valve, inches	4		4		4	
Side of valve on which steam is taken	Inside.		Outside.		Outside.	
	Top.	Bot.	Top.	Bot.	Top.	Bot.
Width of port, inches	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}\times38$	$1\frac{1}{2}\times38$
Steam lap, inches	$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{5}{64}$	$\frac{63}{64}$	1	$\frac{7}{8}$
Exhaust lap, inches	$-\frac{5}{16}$	$-\frac{3}{32}$	$-\frac{1}{8}$	$-\frac{1}{8}$	...	$+\frac{9}{32}$
Angular advance, degrees	$34\frac{1}{2}$	$34\frac{1}{2}$	40	40	45	45
Steam lead, angular, degrees	9	11	8	9	11	14
linear, inches	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{25}{64}$	$\frac{33}{64}$
Cut off, in inches	$23\frac{1}{4}$	$22\frac{7}{32}$	$21\frac{1}{4}$	$18\frac{15}{32}$	$20\frac{5}{8}$	$18\frac{53}{64}$
decimal of stroke	.79	.74	.70	.615	.687	.617
Exhaust release, in inches	$3\frac{15}{64}$	$3\frac{3}{8}$	$4\frac{1}{2}$	$5\frac{3}{16}$	$3\frac{1}{8}$	$3\frac{33}{64}$
decimal of stroke	.123	.112	.15	.172	.112	.117
Compression in inches	$1\frac{1}{2}$	$1\frac{13}{32}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$4\frac{27}{64}$	$4\frac{9}{64}$
decimal of stroke	.041	.048	.075	.0708	.152	.137
Steam opening, inches	$1\frac{3}{16}$	$1\frac{27}{64}$	$1\frac{5}{16}$	1	1	$1\frac{1}{2}$
Exhaust opening	Full port.		Full port.		Full port.	

MEASURED CLEARANCES.

Cylinders.	Vol. clearances.	Vol. clearances.	Lineal clearances.
	cu. in.	*per ct.*	*inches.*
High pressure, port engine, top	1,414	18.4	$\frac{5}{16}$
bottom	1,440	18.5	$\frac{7}{16}$
starboard engine, top	1,410	18.4	$\frac{11}{32}$
bottom	1,416	18.5	$\frac{1}{2}$
Intermediate pressure, port engine, top	2,910	14.3	$\frac{3}{8}$
bottom	3,048	15.3	$\frac{9}{16}$
starboard engine, top	2,627	13.2	$\frac{5}{16}$
bottom	2,764	13.9	$\frac{13}{32}$
Forward low pressure, port engine, top	3,298	11	$\frac{3}{8}$
bottom	3,602	12.1	$\frac{9}{16}$
starboard engine, top	3,235	10.9	$\frac{5}{16}$
bottom	3,650	12.3	$\frac{9}{16}$
Aft low pressure, port engine, top	3,436	11.5	$\frac{13}{32}$
bottom	3,686	12.4	$\frac{1}{2}$
starboard engine, top	3,180	10.7	$\frac{5}{16}$
bottom	3,539	11.9	$\frac{1}{2}$

Cylinders.—The engines are right-and-left, placed in separate watertight compartments. They are of the vertical, inverted cylinder, direct acting, triple expansion type, with two low-pressure cylinders, the arrangement being in the following order beginning forward: Forward low pressure, high pressure, intermediate pressure, and after low pressure. The cylinders are jacketed around working liners. The screws turn inboard.

Framing.—The engines are supported on forged-steel columns, trussed by forged-steel stays. The bed plates are of cast steel, supported on the keelson plates.

Valves.—Each high-pressure valve chest has one, and each intermediate-pressure chest two piston valves. Each low-pressure chest has one double-ported slide valve. All valves are fitted with balance pistons.

Valve Gear.—The valves are worked by double bar links, with slotted arms for varying the cut-offs independently.

Throttles.—The throttles are single-disc stop valves closed by a knuckle-joint arrangement worked by wheels from the starting platform.

Guides.—The ahead crosshead guides are of cast iron, cored out at back for circulating water. The top end is bolted to cylinders, and bottom end to strongback. The backing guides are of cast iron, and are bolted to the ahead guides.

Shafting —The crank shafts are of forged steel in two sections, with the two cranks in each section opposite one another, but coupled so as to bring cranks at intervals of 90 degrees.

Shaft Casing.—The stern tube and propeller shafts are fitted with a composition watertight casing which completely protects them from the action of sea water.

Thrust Bearings.—Are of the horse-shoe type. The horse shoes are ten in number, of composition, lined with white metal, and are held in place by 2½-inch side rods with collars.

Propellers.—The propellers are designed for adjustable pitch from 10 feet 6 inches to 12 feet 6 inches, right-and-left, three bladed, with blades inclined aft 5 inches, measured at the tips. The blades and hubs are of manganese-bronze, the locking plates and covers are of composition, and the bolts are of Tobin's bronze.

Blades, diameter, feet	10
pitch as set on trial, mean, feet and inches	11–6
greatest width of, inches	33½
helicoidal area, starboard screw, square feet	26.85
port screw, square feet	26.73
projected area, each screw, square feet	20.85
disc area, each screw, square feet	78.54
ratio diameter to mean pitch	1 to 1.15
center of hub above lowest point of keel, feet	5.526
tip of propeller immersed, feet	5.224

AUXILIARIES.

Main Air Pumps.—There is a vertical, single-acting, beam air pump, with plungers 22 inches diameter and 10 inches stroke, connected to the forward low-pressure crosshead of each main engine, with discharges to either filter or feed tanks. The buckets have water grooves in lieu of packing. The valves are of manganese-bronze in three thicknesses, each $\frac{1}{32}$ inch in thickness.

Circulating Pumps.—There is a centrifugal circulating pump for each main engine with 12½-inch inlet and 12-inch outlet connections arranged to draw water from the sea, bilge, or main drain, and discharge to condenser or through valve in condenser head overboard. The suction valves are fitted with a locking device, so that only one valve can be opened at a time. A safety sluice is provided in each inboard sea pipe. Each pump is driven by a vertical, inverted, cross-compound engine with cylinders 5 and 10 inches diameter and 6 inches stroke.

Condensers.—There is a cylindrical main condenser placed in the upper outboard corner of each engine room. The shells are of ¼-inch boiler steel, with angle-iron flanges and stiffeners, and are 4 feet 4½ inches inside diameter and 9 feet 2 inches between tube sheets. The tube sheets and glands are of Muntz metal, and the water chests at ends are of composition. There are 2,004 seamless-drawn tubes, ⅝-inch outside diameter, No. 18 B.W.G., with a total cooling surface of 3,005 square feet for each condenser.

Auxiliary Condensers.—There is a horizontal cylindrical auxiliary condenser placed athwartships in the after end of each

engine room. The shells are of plate steel, 23¾ inches outside diameter and 6 feet 1 inch between tube sheets. There are 405 tubes, ⅝ inch outside diameter, No. 18 B.W.G., 6 feet 3 inches long, in each condenser, and the aggregate cooling surface for each is 402.3 square feet. There is a Davidson, horizontal, double-acting, combined air and circulating pump for each condenser, with steam cylinder 6 inches, air cylinder 10 inches, and water cylinder 7 inches diameter and a common stroke of 10 inches.

Feed and Filter Tanks.—There is a 1,500-gallon filter and hotwell tank under each condenser and a 525-gallon feed tank in each engine-room hatch, under line of gun deck. A pipe joins the tops of these tanks, which serves the double purpose of a vapor pipe from the hotwell tank and an overflow pipe from the feed tank. A connection from this pipe leads up through the supply trunk for engine-room blower for the escape of vapor from both tanks.

Feed Heaters.—There is in each engine room a cylindrical feed-water heater placed horizontally, with 374 Muntz metal tubes ⅝ inch outside diameter, 3 feet 11¾ inches long, and No. 18 B.W.G., with a tube-heating surface of 233 square feet in each. The feed water flows by gravity from the feed tanks through the feed heaters to the feed-pump suctions. These heaters worked well on the trials up to the limiting temperature at which the feed pumps would take water.

Reversing Engine.—There is for each engine a single-cylinder, direct-throw, reversing engine, with oil-control cylinder connected to same crosshead. The diameter of steam cylinder is 8 inches and of oil cylinder 4½ inches with a stroke of 10 inches. The admission of steam is regulated by a floating lever in the usual manner. A hand pump connected to the oil cylinder enables the engines to be reversed by hand.

Turning Engine.—There is a double-cylinder turning engine, with cylinders 4 inches diameter by 4 inches stroke, for each main engine. A ratchet is provided for turning by hand.

Forced Draft.—The fire rooms are closed, shutters being provided for closing the hatches at gun deck. There are air locks leading from the after fire room to the engine rooms, between

fire rooms, and from each hatch to passages on the berth deck. There are three forced-draft blowers, with fans 57 inches diameter, each driven by a vertical, inverted, cross-compound engine, with cylinders $4\frac{1}{2}$ and 8 inches diameter by 4 inches stroke. These blowers are in two compartments on the berth deck, and discharge through ducts to the fire rooms, one to the after fire room and two to the forward fire room.

Main Feed Pumps.—There is in each fire room a Davidson vertical, outside-packed, simplex plunger pump, with cylinders 10 inches and 7 inches diameter by 12 inches stroke. Each pump draws water from the communicating pipe between the feed tanks, the water passing through (or by) the feed heaters, from the hotwell tanks, or from the reserve-feed tanks, and discharges into the boilers or to the reserve tanks.

On the builders' trials these pumps were noisy and irregular in their working, particularly with very hot feed water. Additional air chambers were then fitted, one on the suction and one on the delivery side of each pump. On the contract trial the pumps worked much better.

Auxiliary Feed Pumps.—In each engine room there is an auxiliary feed pump of the same size and type as the main feed pumps. They are arranged to draw from the feed, hotwell and reserve-feed tanks, sea, main and secondary drains, engine-room bilge, or from suction-hose connection, and discharge to boilers, fire main, overboard, to hydrant or to ash ejectors.

Ash Ejectors.—An ash ejector of Davidson make is fitted in each fire room. It is connected to the auxiliary feed pumps and discharges through the ship's side, above the water line.

Fire and Bilge Pumps.—In each engine room there is a 7-inch by 7-inch by 12-inch Davidson simplex, vertical pump, arranged to draw from sea, main and secondary drains, double-bottom manifold, engine-room bilge, crank-pit well, or from suction hose, and discharge to sea, to fire main or to hydrant. A similar pump is placed in each fire room, but has an additional suction from boilers. The pump in the starboard engine room also has a discharge to spray nozzles on furnace fronts for extinguishing the fires on the grates.

Water Service and Distiller Pumps.—In each engine room there is a 7-inch by 7-inch by 12-inch Davidson simplex, vertical pump, arranged to draw from the sea only and discharge to engine-room water service, to fire main or to the distiller circulating pipes, by which the water may be passed through the distillers or around them to the flushing system or overboard.

Hotwell Pumps.—In each engine room there is a 7-inch by 7-inch by 12-inch Davidson vertical, simplex plunger pump, arranged to draw from hotwell tank, air-pump suction pipe, reserve-feed tanks or filling pipe, and to discharge to feed tank or reserve-feed tanks.

Shaft Bilge Pumps.—At the forward end of each main shaft there is a 4-inch by 5-inch pump driven by an eccentric, arranged to draw from the crank-pit drainage well or from the secondary drain and to discharge overboard.

Ash Hoists.—There is in each fire-room hatch, on gun deck, a double-cylinder, reversible, ash-hoist engine of the contractors' design, with cylinders 4 inches diameter by 4 inches stroke.

Ice Machine.—There is a 1-ton Allen dense air ice machine in a compartment on the berth deck, with cold-air pipes leading to the freezing tank and the cold-storage rooms adjoining, and to scuttle butt on the gun deck above.

Distilling Plant.—There is a horizontal evaporator of 5,000 gallons daily capacity on the grating in the after end of each engine room, and a vertical distiller of corresponding capacity in each engine-room hatch. Both evaporators and distillers were built by the contractors on plans similar to those of the well-known Bureau of Steam Engineering type. The distilled water descends to fresh-water tanks in engine rooms, from which it is pumped to the ship's tanks. The evaporator feed pumps are of the Davidson vertical, simplex type, with cylinders $4\frac{1}{2}$ and 4 inches diameter and 6 inches stroke. The fresh-water and brine pumps are combined, with water cylinders $2\frac{3}{8}$ inches diameter, and a single horizontal steam cylinder 4 inches diameter by 5 inches stroke.

Workshop Machinery.—The engine is vertical, with single cyl-

inder 6 inches diameter by 5 inches stroke. The tools are as follows:

One 24-inch by 10-foot bed, engine lathe.
One 12-inch by 4-foot bed, tool-room lathe.
One drill press for drills up to 1¼ inches.
One 16-inch sensitive drill.
One 15-inch by 24-inch column shaper.
One emery grinder, with two 12-inch wheels.
One large grindstone.

One 5½-inch vise is fitted in workshop. A vise bench, with three vises, has been placed in the forward blower room adjoining the workshop. A bench, with small vise, is fitted for use in the starboard engine room, and a portable bench, with blacksmith's vice, for use in the fire rooms or on deck.

Windlass.—The windlass is of the contractors' design. There are two horizontal cylinders 8 inches diameter by 10 inches stroke. The power is transmitted to the wildcats through spur gearing, no worm wheel being employed. The machine is therefore elastic, and, if the strain on chain be great enough, will walk back against the steam pressure, thus preventing undue strain. A simple friction clutch, with screw-down connection, throws the wildcats in or out of gear, and a brake with wheel regulates the movement of chain in paying out. The wildcat is of improved design, taking shackles without difficulty. The windlass met the severe tests prescribed by the Bureau of Construction and Repair without heating or mishap of any kind.

Capstan Engine.—A two-cylinder, 6-inch by 6-inch by 8-inch horizontal engine on the upper deck operates the capstan independently of the windlass.

Steering Gear.—The engine, designed and built by the contractors, is vertical, with two cylinders of 7 inches diameter and 6 inches stroke, with differential valve, and communicates its motion to the rudder by the usual right and left hand screw mechanism. A small wheel on the bridge, another at the engine, and the large wheel on quarter deck may be used for steering by steam. The wheel on the quarter deck, as well as the hand wheel in the steering-engine room, permit steering by

hand. The rudder head passes through the protective deck, and is fitted with a tiller, wire tiller ropes and relieving tackles in the after portion of wardroom.

BOILERS.

There are six Babcock & Wilcox boilers, of the *Alert* type, placed in two compartments, four boilers being in the forward compartment and two in the after compartment. They are similar in all respects to those of the *Cleveland*, described on page 1122, Vol. XV, of the JOURNAL.

Width, external, feet and inches	11–10
Height, external, feet and inches	12– 3
Length, external, feet and inches	12–10
Number of furnaces in each	1
Type of furnace, full width of boiler, three doors to each.	
Height of furnace, internal, front, inches	26¼
back end of grate, inches	38½
Width of furnaces, internal, least, inches	92½
greatest, inches	92½
Length of grates, feet and inches	6– 6
Working pressure, pounds per square inch	275
Grate surface, each boiler, square feet	50
total, square feet	300
Heating surface, each boiler, square feet	2,200
total, square feet	13,200
Ratio of grate to heating surface	1 to 44
Tubes in each boiler, 17 4-inch diameter, 8 feet 9 inches long, No. 6 B.W.G.	
15 4-inch diameter, 6 feet 11 inches long, No. 6 B.W.G.	
406 2-inch diameter, 8 feet 9 inches long, No. 8 B.W.G.	
Smallest area for passage of gases, each boiler, square feet	8.19
Grates, fixed or shaking	Fixed.
Funnel, area of, forward, square feet	14.75
after, square feet	28
height above grates, feet	70

Funnels.—The uptakes for the four after boilers lead to the after funnel, and those of the two forward boilers to the forward funnel. The divisions between uptakes are carried only as far up as the gun deck, but each is fitted with an independent damper.

The funnels are each 6 feet 8¼ inches outside diameter. The forward funnel is 4 feet 4 inches and the after funnel 6 feet 1 inch

inside diameter. The galley smoke pipe, 14 inches diameter, is carried up inside the after funnel.

PIPING.

Main Steam Pipe.—The two main steam pipes are of seamless steel with male and female flanged joints. They are independent, excepting for a cross connection with valve between the engine rooms and a second connection with valves in the dynamo room. Each pipe extends fore-and-aft from the dynamo rooms to the main engines and has a 4-inch branch to each boiler on its own side. From the forward boilers to the dynamo room the pipes are 3 inches diameter, from the forward to the second boilers, 4 inches diameter, from the second to the after boilers, 5½ inches diameter, and from the after boilers to the engines, 6 inches diameter. Cut-out stop valves are placed in each pipe in the forward end of each boiler room. The engine stop valves are immediately abaft the separators in forward end of the engine rooms.

Auxiliary Steam Piping.—The auxiliary steam pipes are connected to and take steam from the main separators. For the engine-room auxiliaries the pipe forms a loop around the engine rooms connecting the two main separators. For the fire-room and forward-deck auxiliaries there is a branch from each main separator leading to the auxiliary separator in the after fire room. From this separator the auxiliary steam pipe leads up the hatch and forward under the gun deck. Branches from this pipe in the after fire room are led to the fire-room pumps, to coal-bunker fire extinguishers, and to hose valves for cleaning boilers. Branches in wake of the various auxiliaries lead to ash hoists, heaters, whistle and siren, forced-draft blowers, ice machine, workshop engine, windlass and capstan engine. The branch to the whistle is provided with a separator and trap which have no other connections.

All the above piping exceeding 2 inches diameter is of seamless steel. Below 2 inches diameter it is of seamless-drawn copper. The joints are made with corrugated copper gaskets and have male and female flanges.

Auxiliary Exhaust Pipe.—Is of copper, 6 inches diameter, with branches from all auxiliary machinery and valves for exhausting through after escape pipe to atmosphere, to each main and each auxiliary condenser and to each low-pressure receiver. The exhaust may be passed through the feed heaters when desired.

Drainage Mains.—A 1½-inch pipe leads from dynamo room on each side aft to the engine room. To these are run the drains from the various steam auxiliaries in wake of them, as well as the discharges from the various steam traps throughout the ship. The two mains are connected, with cut-out valves in the engine and dynamo rooms, and lead to the main or auxiliary condensers, hotwell tanks or bilges.

Heater System.—A branch from the auxiliary steam pipe leads to the heater manifold in the after fire-room hatch. This has branches as follows:

Circuit No. 1, to galley, forward bath heaters, and to radiators in sick bay, chart house and pilot house.

Circuit No. 2, to berth deck forward.

Circuit No. 3, to berth deck aft.

Circuit No. 4, to pantries and after bath heaters.

Circuit No. 5, to gun deck forward.

Circuit No. 6, to gun deck aft.

Circuit No. 7, to drying room.

Brass pipe coil heaters are used throughout the ship. Standard-size regrinding globe valves are employed on the steam side, and standard-size check valves on the drain side of all heaters. The drains from the forward heaters lead to traps in the after fire-room hatch, and from the after heaters to traps in the engine room.

Steam Traps.—All steam traps are of the MacKellar patent float type.

Reducing Valves.—Are of the Leslie type, and are fitted on heater circuits and on steam pipes to all auxiliaries where a reduced pressure is required.

Fire Extinguishers.—Spray nozzles for extinguishing the fires on grates are fitted to the furnace front of each boiler. The pipes have a separate branch, with stop valve to each boiler,

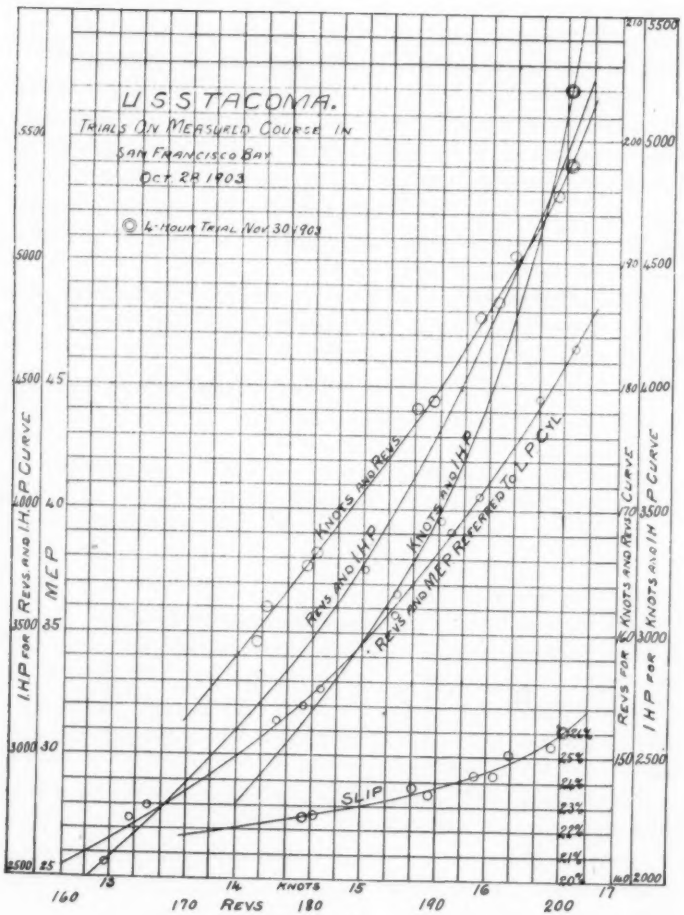

U S S TACOMA.
TRIALS ON MEASURED COURSE IN
SAN FRANCISCO BAY
OCT 28 1903
4 HOUR TRIAL NOV 30 1903
IHP FOR REVS AND IHP CURVE
MEP
REVS FOR KNOTS AND REVS CURVE
IHP FOR KNOTS AND IHP CURVE
KNOTS AND REVS
REVS AND IHP
KNOTS AND IHP
REVS AND MEP REFERRED TO L P CYL
SLIP
KNOTS
REVS

FIGURE I

and connect to the fire and bilge pump in the starboard engine room.

A steam pipe is carried to each coal bunker, the end being led along the bottom of bunker and pierced with holes in order to permit as great a distribution of steam as is possible.

DOCK TRIALS AND TESTS.

Steam, to 325 pounds pressure, was raised on all the boilers for the purpose of testing boilers and steam lines, September 15th to 18th, 1903. It is worthy of note that on this test not a single joint in steam piping showed a leak.

October 6th steam was turned on the main engines, and they were given dock trials for purposes of adjustment until October 8th. On the latter date a card from the port intermediate cylinder indicated injury to the diaphragm in valve chest. An examination showed the lower inboard valve chest liner fractured through bridges. This was renewed and bored out in place.

BUILDERS' TRIALS.

October 28th the *Tacoma* left the dock under her own steam for the first time. A series of runs was made over the measured course in San Francisco Bay with results as shown on page 22.

REMARKS.

Length of course, 6,137½ feet. Sea smooth. No wind. Started the runs with high and intermediate-pressure links hard up in the slot of reversing arm. Before going on No. 7 run, moved the intermediate links out. Before going on No. 9, moved the high-pressure links ½ out. Before going on No. 11, moved the high-pressure links full out. All passovers open on No. 14 and closed on No. 15. Indicator cards from starboard engine only. Receiver gauges held as nearly as possible alike. Stack temperatures taken with metallic pyrometers which were not tested. The air pressure at no time exceeded 1 inch of water.

Assuming the horsepower of the port engine to be the same as of the starboard engine, the results of these runs are plotted on the curves shown in Figure 1. The point indicated by the

	Time going on course.	Elapsed time.	Revolutions per minute.			Speed.	M. E. P. referred to L. P. cyl.	Steam pipe.		First Rec		Second Rec.				Vaccum.		Stack.		Direction.	
												For'd.		Aft.							
			Port.	Stbd.	Mean.			P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	F.	A.		
1	12'21	241½	157.9	158.5	158.2	15.06	...	...	...	...	...	...	...	...	...	...	...	...	...	S.	1
2	12 37	274	160.3	160.3	160.3	13.26	...	...	..	...	...	...	...	...	...	...	...	...	...	N.	2
					159.3	14.16															Mean of 1 and 2.
3	12'51	238¾	164.2	163.2	163.7	15.24	25.57	222	234	37	45	...	0	1½	½	28	27	400	552	S.	3
					162.0	14.25															Mean of 2 and 3.
4	1'04	262	167.0	167.0	167.0	13.86	27.90	232	246	38	50	0	1	0	1	28	27	400	465	N.	4
					165.3	14.55															Mean of 3 and 4.
5	1'18	236	166.2	165.0	165.6	15.40	27.40	230	250	38	50	0	1	0	½	28	27	405	468	S.	5
					166.3	14.63															Mean of 4 and 5.
6	1'32	246	180.8	178.0	179.4	14.76	32.11	262	270	54	62	...	3½	5	3	28	27	440	590	N.	6
7	1'44	226	177 9	176.1	177.0	16.08	31.37	...	...	...	...	...	...	...	...	...	...	...	...	S.	7
					178.2	15.42															Mean of 6 and 7.
8	1'53	242	181.8	179.7	180.8	15.02	32.71	248	253	55	55	...	4½	5	4	28	27	430	602	N.	8
					179.9	15.55															Mean of 7 and 8.
9	2'11	220	188.1	185.4	186.8	16.52	36.60	250	250	70	65	...	7½	6½	7½	27	27	425	635	S.	9
10	2'25	232½	188.3	184 8	186.6	15.62	35.71	245	253	66	63	...	7	7	7	27	27	440	628	N.	10
					186.7	16.07															Mean of 9 and 10.
11	2'37	224	185.4	182.9	184.2	16.22	37.46	210	220	72	72	...	10	10	9	26	27	440	622	S.	11
					185.4	15.92															Mean of 10 and 11.
12	2'51	225½	192.8	189.2	191.0	16.10	39.06	225	230	77	77	...	11	11	10	25	27	482	632	N.	12
13	3'03	223½	191.3	189.1	190.2	16.28	39.52	225	307	77	77	...	11½	10½	10	26	26½	469	638	S.	13
					190.6	16.19															Mean of 12 and 13.
14	3'16	216½	199 5	196.1	197.8	16.78	44.50	245	225	90	92	15	16½	16½	15½	26	26½	501	652	N.	14
15	3'28	223½	195.6	190.9	193.2	16.28	40.48	235	238	77	78	13	12	14	12	27	27	460	645	S.	15
					195.5	16.53															Mean of 14 and 15.

double circle is from the four-hour trial on November 30th, taking the speed at 16.62 knots per hour.

These trials indicated that the contract speed could be obtained without exceeding the allowed air pressure. It was determined, however, to alter the setting of the high-pressure valves slightly, to permit the admission of more steam, and to trim the vessel down slightly by the stern. Additional air chambers were also fitted on the main feed pumps, as already noted.

The changes in valve setting and in pumps undoubtedly contributed to the successful contract trial which followed. The change in trim probably caused little improvement, as on each trial a solid wall of water, 4 or 5 feet in height, appeared to be pushed ahead of the ship, breaking about 30 feet abaft the stem.

On November 27th, the *Tacoma* having been made ready for the contract trial, was taken out for a few hours' cruise in San Francisco Bay for the purpose of adjusting compasses. No attempt to speed the vessel was made on this trial.

CONTRACT TRIAL.

On November 28th, the members of the Trial Board and its assistants having assembled on board, the *Tacoma* left the Union Iron Works at 10·30 A. M., and put to sea, arriving off Santa Barbara, California, at noon on the 29th. The *Adams*, *Petrel*, *Perry* and *Fortune*, were found in port and they, having been assigned to duty as stake boats, took positions on the course on the afternoon of this day.

The course was the one laid down for the trial of the *Wisconsin*, 32.0005 nautical miles in length, extending in a direction S. 79° E. from Point Concepcion nearly to Santa Barbara light. Ranges on shore mark the extremities, and in no place is the depth of water less than 30 fathoms. The current is slight and is practically constant in force and direction. These conditions make the course as nearly perfect as it is possible to obtain for a trial over a measured course.

On the morning of the 30th the *Tacoma* got under way and steamed twice over the course, steering a compass course on each run. Times and speeds as follows:

	H.	M.	S.
Run West.			
Time of passing 1st range,	8	41	48.5
2d range,	10	34	29
Elapsed time,	1	52	40.5
Speed (uncorrected), 17.04 knots.			
Run East.			
Time of passing 1st range,	10	42	49.5
2d range,	12	41	21
Elapsed time,	1	58	31.5
Speed (uncorrected), 16.20 knots.			
Mean speed (uncorrected), 16.62 knots.			

The stake boats were stationed at intervals of about eleven miles. Their observations for current were taken with poles loaded to float at a depth corresponding to the draught of the ship. The mean result of the different series of observations, when reduced to the course steered by the ship and applied, each to its own portion of the course, produced corrections as follows:

Run west, correction, knots,	(—)0.4173
Distance run, knots,	31.5822
Speed (corrected), knots,	16.8177
Run east, correction, knots,	(+)0.2978
Distance run, knots,	32.2983
Speed (corrected), knots,	16.3501
Mean speed (corrected), knots,	16.5839

During the trial, temporary counters having been placed on deck, they were read at intervals of five minutes by a representative of the contractors, and the results communicated to the chief engineer in charge in the engine rooms. The results of these readings are shown graphically in Figure 2.

It will be noted that the speed, both corrected and uncorrected, was considerably less on the run east, although the revolutions on this run were considerably greater. This is partially accounted for by a swell which struck the vessel on the starboard quarter on this run, making it impossible to keep her ac-

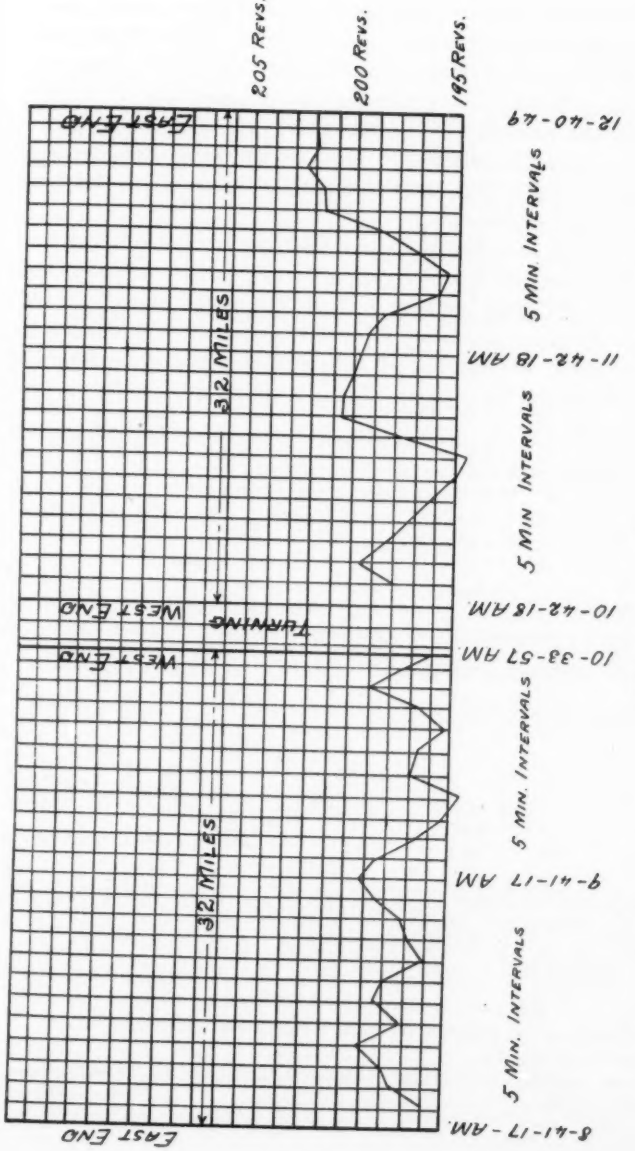

205 Revs.
200 Revs.
195 Revs.
12-40-49
5 MIN INTERVALS
11-42-18 AM
5 MIN INTERVALS
10-42-18 AM
10-33-57 AM
5 MIN. INTERVALS
9-41-17 AM
5 MIN. INTERVALS
8-41-17 AM
32 MILES
TURNING
32 MILES
EAST END
WEST END
WEST END
EAST END

FIGURE 2

curately on her course. Another probable cause is the unsatisfactory character of the tidal observations. The observing vessels were small, and they were anchored in depths varying from 30 to 70 fathoms. They were probably constantly in motion, and the observations merely represented the difference in movement of the vessel and pole. This was shown in some cases by widely varying results, both in force and direction, in the same series of observations.

At the conclusion of the speed trial, the tests of windlass and steering gear, prescribed by the Bureau of Construction and Repair, were made, and at 8 P. M. the vessel started on the return to San Francisco. A speed of 14 to 15 knots under natural draft was maintained during this run, and anchor was dropped off the Union Iron Works wharf at 4·30 P. M. on December 1st.

PERFORMANCE.

Steam pressure at boilers (per gauge), pounds	268
H. P. steam chest, S. engine (per gauge), pounds	245.65
P. engine (per gauge), pounds	247.3
1st receiver, S. engine, absolute, pounds	106.7
P. engine, absolute, pounds	108.2
2d receiver, S. engine, absolute, pounds	30.65
P. engine, absolute, pounds	31.78
Vacuum in condensers, in inches of mercury	P., 26.9; S., 27.32

MEAN EFFECTIVE PRESSURES IN CYLINDERS IN POUNDS PER SQUARE INCH.

Main engines, starboard, H.P.	103.31
I.P.	50.59
F. L.P.	14.74
A. L.P.	15.28
port, H.P.	94.08
I.P.	48.24
F. L.P.	16.25
A. L.P	16.18
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	44.79
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, port	44.05

AUXILIARY MACHINERY.

Pumps, air, main, attached to main engine, circulating, main, one engine	H.P., 78.14; L.P., 36.42
Dynamo engines	Not indicated.
Blower engines	Not indicated.

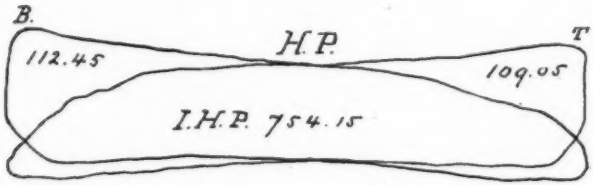
REVOLUTIONS PER MINUTE.

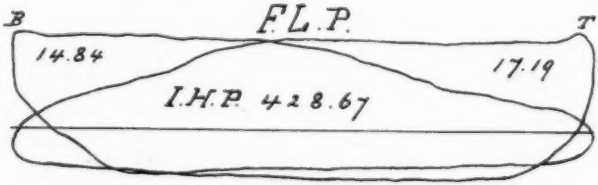
Main engines, starboard	195.49
port	200.55
Pumps, circulating, starboard	274.1
port	249.0
feed, double strokes per minute	25.5
auxiliary, water service	35
bilge	35
hotwell	35
Blower engines, starboard, forward	664
port, forward	665
after	796
Speed of ship, in knots per hour	16.5839
Slip of propeller, in per cent. of its own speed, based on mean pitch,	S., 25.26; P., 27.03
Air pressure in ash pits, inch of water	0.965

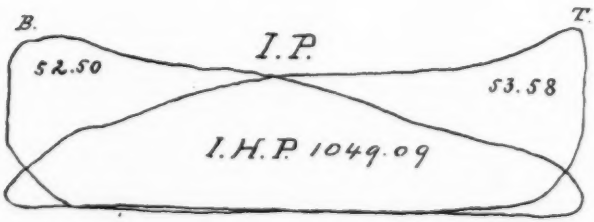
INDICATED HORSEPOWER.

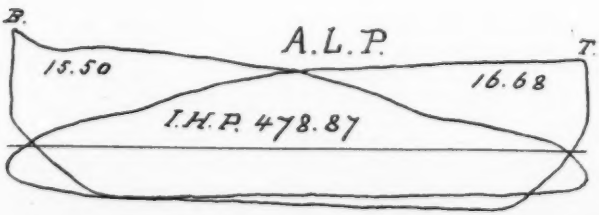
Main engines, starboard H.P.	754.15
I.P.	978.03
F. L.P.	428.67
A. L.P.	444.49
total	2,605.34
port H.P.	704.71
I.P.	956.05
F. L.P.	484.21
A. L.P.	482.72
total	2,628.19
Circulating pump, starboard engine	17.67
port engine	14.61
Feed pumps, two main	22.21
Bilge pumps, starboard engine	6.5
port engine	6.5
Water-service pumps, starboard engine	6.5
port engine	6.5
Hotwell pumps, starboard engine	6.5
port engine	6.5
Ventilating engines, for ship, electric; for engine rooms, electric.	
Blower engines, for forced draft in fire rooms (estimated)	57
Dynamo engines (calculated from current and voltage)	40
Collective of all main engines and air pumps	5,233.43
main engines, air, circulating and feed pumps	5,287.92
and auxiliary engines in operation during trial	5,423.92
all machinery during trial, per square foot of G.S.	18.08
H.S.	0.411
Main engines, air, circulating and feed pumps, per square foot of G.S.	17.626
H.S.	0.401

STBD ENGINE.

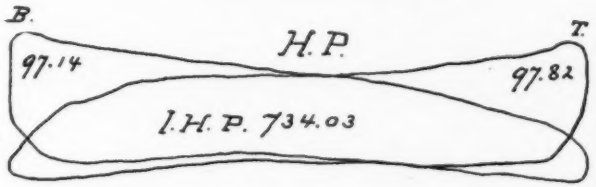

B.
H.P.
T
112.45
109.05
I.H.P. 754.15

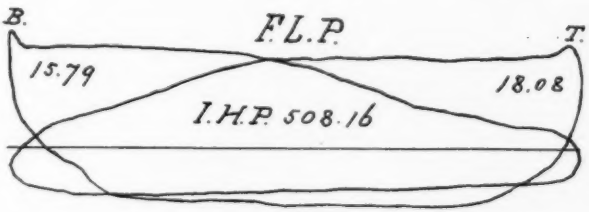

B
F.L.P.
T
14.84
17.19
I.H.P. 428.67

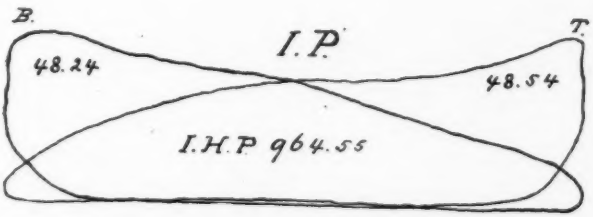

B.
I.P.
T.
52.50
53.58
I.H.P. 1049.09

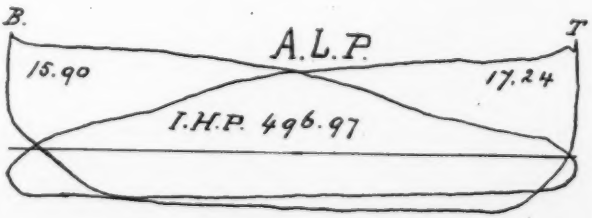

B.
A.L.P.
T.
15.50
16.68
I.H.P. 478.87

PORT ENGINE.


B.
T.
H.P.
97.14
97.82
I.H.P. 734.03


B.
T.
F.L.P.
15.79
18.08
I.H.P. 508.16


B.
T.
I.P.
48.24
48.54
I.H.P 964.55


B.
T.
A.L.P.
15.90
17.24
I.H.P. 496.97

COAL.

Kind and quality, Harris' deep navigation, hand picked.

Pounds per hour	11,730
per I.H.P., collective, all machinery in operation	2.16
main engines, air, circulating and feed pumps	2.22
square foot of G.S	39.1
H.S	0.89
Cooling surface, square feet per I.H.P	1.11
Heating surface, square feet per I.H.P	2.43

The accompanying set of indicator cards is the maximum set, taken just before the conclusion of the trial.

NOTES.

Trial Crew.—The trial of the *Tacoma* was, on the part of the contractors, under the general direction of Mr. Robert Forsythe, the chief engineer of the company. The officers and crew in the engineer department were as follows:

In the engine rooms:

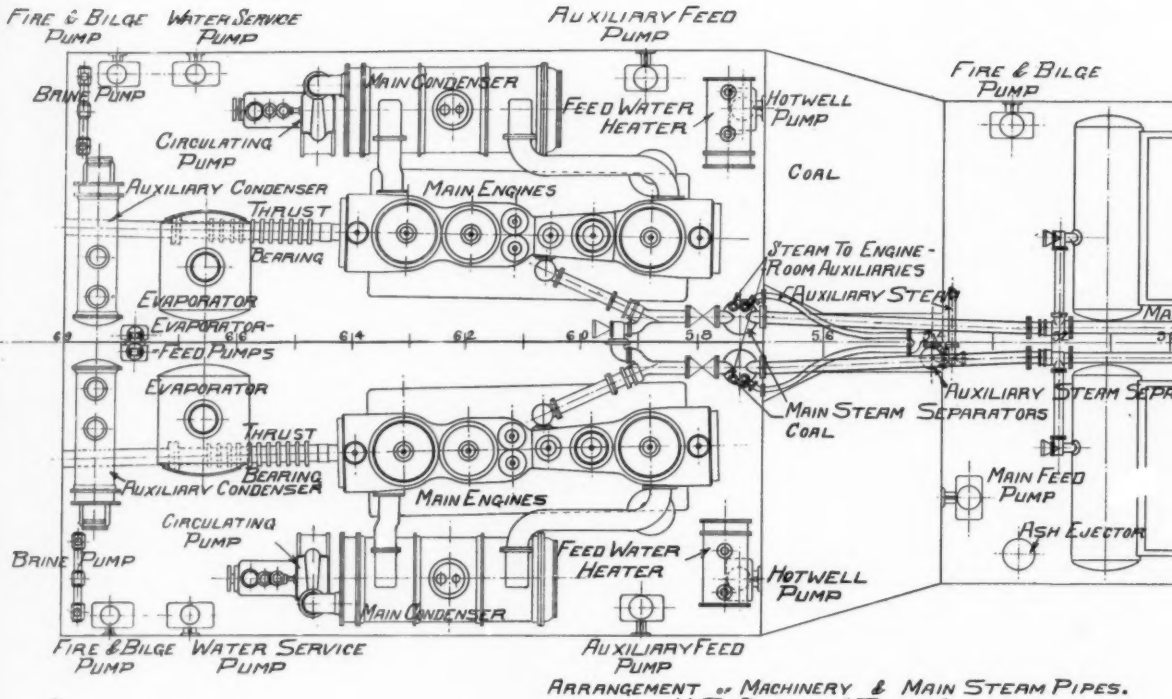
1 Chief engineer.
2 Engineers.
14 Machinists and oilers.

In the fire rooms:

1 Engineer.
3 Water tenders.
14 Firemen.
6 Coal passers.

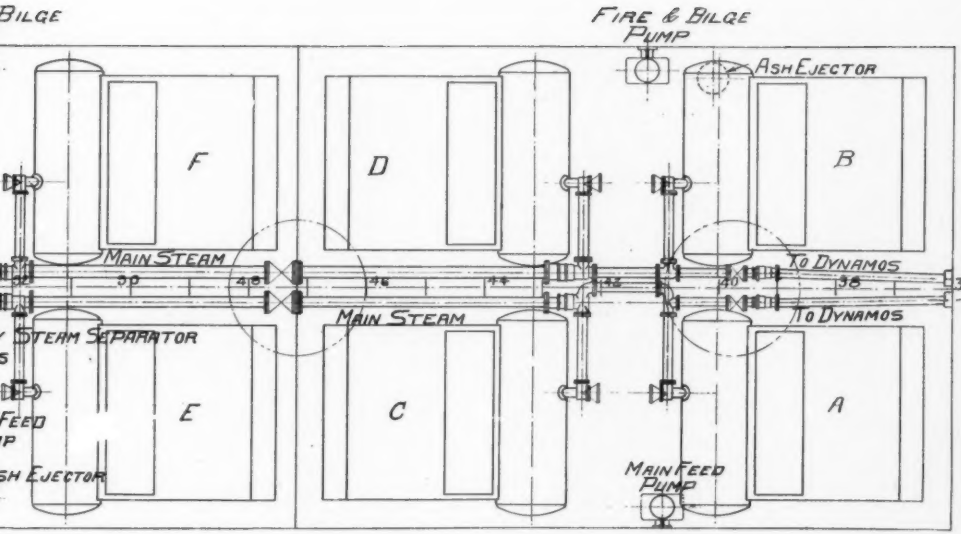
Automatic Timing Device for Firing.—A specially interesting feature of the trial was the device for timing automatically the operations of the firemen. An illuminated dial with six numbers on it is placed in each fire room. Each number has a lamp behind it, and contact is made and broken in turn by a small electric motor, with rheostat for regulating its speed of rotation. A bell rings when a contact is made, and the furnace doors, having been numbered to correspond with the numbering on the dial, the particular door indicated is opened for working the fire.

On the run down the coast this apparatus was operated for the purpose of training the fire-room force in its use, the speed



ARRANGEMENT OF MACHINERY & MAIN STEAM PIPES.
U.S. CRUISER "TACOMA"

FIG. 3


BILGE
FIRE & BILGE PUMP
ASH EJECTOR
F
D
B
MAIN STEAM
TO DYNAMOS
30
48
46
44
42
40
38
36
MAIN STEAM
TO DYNAMOS
STEAM SEPARATOR
FEED
SH EJECTOR
E
C
A
MAIN FEED PUMP

PIPES.

being then regulated for a 2-minute interval. On the contract trial the interval was 40 seconds, the firing was of the best, and steam was maintained with great uniformity. There was no noise or confusion caused by passing orders to the firemen, and the very successful results achieved were in a considerable measure due to the use of this apparatus.

Working of Machinery.—On the trial, the engines ran with great steadiness, no appreciable vibration of either engines or hull being noticed. An examination of the machinery after the trial showed no cutting or other injury of any kind. The boilers were free from grease and were clean, with the exception of a slight deposit of mill scale which appeared lying loose in some of the tubes. This was all carefully removed with brushes before the delivery of the vessel.

Workmanship.—The workmanship on the *Tacoma* is well in keeping with the high standard established by the Union Iron Works in the vessels previously built by them for the Government. The manner in which the machinery and the various appurtenances required by the specifications have been stowed in the engine rooms, without sacrificing the accessibility of any part, speaks in the highest manner for the skill and ingenuity of the company's engineering staff. The arrangement in engine and fire rooms is shown in Fig. 3.

Penalty Weight.—The weight of machinery was limited by the contract to 427 tons, a penalty of $500 per ton being stipulated for any weight in excess of this amount. The machinery, complete, ready for delivery, weighs slightly in excess of 438 tons, from which it will appear that the builders will forfeit as penalty the sum of $5,500.

In the *Tacoma*, as in other naval vessels, all the details of the machinery installation were clearly specified, and all drawings were submitted and approved before work was begun. The details of construction were subjected to a rigid inspection, to see that all provisions of the specifications were complied with. It appears, then, that the power to limit the weight of machinery was taken out of the hands of the builders, and that any system of penalizing them for an excess weight of machinery, under

such conditions, is unfair. It is certain that eleven tons' weight could not be taken from the *Tacoma's* machinery without seriously impairing its efficiency, unless parts of the specifications were eliminated or disregarded.

CHANGES.

No vital change in the machinery was found necessary. It was deemed advisable, however, and the Trial Board recommended, that the distilling plant be removed from engine rooms to a location on gun deck. The evaporators greatly crowd the after part of engine room, creating a very high temperature, and endanger getting grit into the thrust and other bearings when the tubes are scaled. As now located, the evaporators are so widely separated that it will be difficult for one man to attend both.

METHODS OF CONDUCTING TRIALS.

The Measured Course.—The method of conducting the *Tacoma's* trial was that followed by the Department in the trials of all the larger vessels of the Navy. The method is so inaccurate as to make it extremely improbable that the report of any single trial conducted by it has given the true speed of the vessel. The method is open to the following objections:

(1) The difficulty of laying down and marking accurately a suitable deep-water course of the proper length. On the Santa Barbara course this objection does not apply, since the course lies close to and runs parallel with the shore line, and the extremities are marked with range beacons. On the Cape Ann course, and other courses that have been used for trials, the ends of the course are marked with buoys, the positions of which are plotted from ranges. Buoys are also placed at intervals along the course to mark positions for stake boats for the vessel under trial to steer by. The work of locating the buoys must be very carefully done to ensure accuracy, and since they are moored in deep water, they cannot be relied on to maintain their exact positions.

(2) Difficulty in steering the course correctly. At Santa Barbara a compass course is steered, this being made possible by

the small cross current. On other courses the steering is from stake boat to stake boat. It is customary to use as stake boats tugs which go out and anchor near the several buoys. It is doubtful if they are ever accurately in line.

(3) Difficulty in observing the force and direction of the tide with accuracy, or in obtaining and applying the proper correction for current. The method in use is that described above, and is inaccurate for the reasons given. Even if correct observations could be obtained, there should be a much greater number of stations to obtain results approaching accuracy.

The unreliability of tidal corrections is so great as to make this difficulty alone a sufficient cause for discarding this method of conducting trials. There is grave doubt of even the approximate correctness of any tidal correction obtained as above described. It is believed that no correction based upon such questionable observations should ever be applied to the observed speed of a vessel to cause the infliction of an increased penalty for deficiency in speed upon the builders.

(4) The greater expense to both the Government and the builders when compared with the standardized-screw method.

(5) Fine weather is necessary. In December, 1902, the monitor *Nevada*, built at Bath, Maine, was detained at Boston for ten days awaiting a favorable day for a trial over the Cape Ann course.

The Standardized-Screw Method.—In 1892, through the representations of Engineer-in-Chief George W. Melville, the Department authorized the trial of the *Bancroft* by this method. A series of runs was made over the measured mile with the vessel in trial condition, from which the results were plotted to obtain a curve of speeds and revolutions. The number of revolutions necessary to make the required sustained speed was taken from this curve, and the vessel, again brought to trial condition, was run out to sea with the requirement that she make this number of revolutions.

This trial was highly successful, but the Navy is conservative, and, outside of engineering circles, the method did not immediately meet with favor. The Engineer-in-Chief continued to ad-

vocate it, and when the torpedo boats and destroyers were built the Department adopted it for the trials of these vessels. It has also been used for some of the smaller vessels of the cruiser class and for two of the new monitors. Experience has demonstrated to builders and to officers who have actually conducted trials by both methods that the standardized-screw method is superior, though, as yet, the Department has not been persuaded to adopt it for larger vessels.

As compared with a trial over a measured course, this method offers the following advantages:

(1) A measured mile may be located much more easily and can be measured and permanently marked with absolute accuracy.

(2) No difficulty in steering. After standardizing the screws the speed is observed by taking the number of revolutions, and a course straight out to sea is usually employed for the sustained speed trial.

(3) No tidal corrections are necessary. The measured mile is laid off in the direction of flow of the tide, and the mean of a run with and against the tide gives the true speed.

(4) Trials may be conducted in the vicinity of the builders' works without incurring the expense involved by carrying on trials at a great distance from base. The expense to the Government involved by the use of commissioned vessels as stake boats is obviated.

(5) If the weather is fine enough to permit the measured-mile trials over a sheltered course, the sustained speed trial at sea may be made in rough weather. In the case of the *Nevada*, before cited, if the standardized-screw method had been employed, the trials could have been conducted on the first day. Aside from the added expense to the Government and the builders that would have been obviated, the Trial Board and its assistants would have been released and permitted to return to other duties.

PROPELLER DATA.

The standardized-screw method affords a means of obtaining screw data which, if followed for all of our ships, would be of incalculable value. It is the policy of the Bureau of Steam

Engineering to permit builders to design their own propellers, they being responsible for the speed of vessels built by them. For vessels of the same class the conditions of loading on trial are the same, so that the results of the trials afford a direct means of comparison of propellers of different design. With six vessels of the *Pennsylvania* class, five of the *Louisiana* class, three of the *St. Louis* class, six of the *Tacoma* class and four of the *Arkansas* class, such trials would contribute data which should solve definitely the question of propeller design that now vexes engineering authorities everywhere, and contribute vastly to the increased efficiency of our fleet.

NEW 13,000-TON BATTLESHIPS *MISSISSIPPI* AND *IDAHO*, NOS. 23 AND 24.

By W. F. Sicard, Esq.

By an Act of Congress, approved March 3, 1903, provision was made for the construction of three first-class battleships of a trial displacement of not more that 16,000 tons; two first-class battleships of a trial displacement of 13,000 tons, and three training ships.

The three 16,000-ton and two 13,000-ton battleships are to be built under the provisions of the Act of August 3, 1886, as to material for hulls, engines, boilers, etc., except that no premiums are to be offered, and that all parts shall be of domestic manufacture. Not more than two of the five battleships may be built by one contracting party, and further authority was given the Secretary of the Navy that he "may build any or all of the vessels herein authorized in such navy yards as he may designate, and shall build any of the vessels herein authorized in such navy yard as he may designate, should it reasonably appear that * * * the bidders * * * had entered into any combination to restrict competition."

The contracts for the three 16,000-ton battleships, the *Vermont*, *Kansas* and *Minnesota*, Nos. 19, 20 and 21, have already been let, and these vessels have been described in the Journal. The bids for the two 13,000-ton ships, however, have been opened only recently, owing to various delays brought about by the wording of the Act and by the desire of the Department to lay down the best possible ships in conformity with that Act.

The time that elapsed between issuing the circulars inviting bids for the 16,000-ton and those for the 13,000-ton vessels was occupied by the Department in endeavoring to secure the best possible combination of armor, armament, speed and coal capacity on this limited displacement of 13,000 tons. Many and varied designs were proposed, and it was only after an exhaustive con-

sideration of each, in all its details, that the final design, as outlined in the circular, was adopted.

In accordance with the Act, these ships were to carry the heaviest armor and most powerful ordnance for vessels of their class upon a trial displacement of 13,000 tons; to have the highest practicable speed and great radius of action; and to cost, exclusive of armor and armament, not exceeding $3,500,000 each.

The circular inviting bids for the 13,000-ton battleships was issued from the Navy Department under date of November 7, 1903. It calls for vessels of 13,000 tons trial displacement, to make a speed of 17 knots an hour for four consecutive hours, and the maximum time allowed for completion is limited to forty-two months. There are the usual penalties for underspeed and overtime.

The bids were opened at the Department, at noon, January 15th, 1904, and were as follows:

.....	One ship.	Time.	Two ships.	Time, first.	Time, second.
		mos.		*mos.*	*mos.*
Newport News S. B. & D. D. Co..	$3,147,000	37	.....	...	...
Wm. Cramp & Sons' S. & E. B. Co.	3,200,000	39	$2,999,500	38	40
N. Y. Shipbuilding Co.....	3,500,000	42	(each)	...	...
Fore River Ship and Engine Co...	3,468,000	42	.....	...	...
Maryland Steel Co.....	3,472,000	42	.....	...	...

As two similar vessels building at the same yard and at the same time can be constructed for less than double what one would cost if built alone, it can be seen that a certain disadvantage resulted to those yards which had already contracted for one of the 16,000-ton battleships, since this act limited a single bidder to two ships out of the five. The contracts for both vessels were awarded to the lowest bidder, the Wm. Cramp & Sons' Ship and Engine Building Co., of Philadelphia, Pa.

Before giving a detailed description of these vessels it may be interesting to compare some of their principal characteristics with two recent types of battleships of nearly the same size and power, the *Kearsarge* and the *Alabama* (pages 38 and 39).

	Kearsarge.	*Alabama.*	*Mississippi.*
Contract date	January, 1896	September, 1896	January, 1904
price	$2,250,000	$2,650,000	$2,999,500
time of completion	36 months	36 months	39 months
Trial displacement	11,550 tons	11,562 tons	13,000 tons
Length on water line	368 feet	368 feet	375 feet
Breadth on water line	72 feet	72 feet 2½ inches	77 feet
Mean trial draught	23 feet 6 inches	23 feet 6 inches	24 feet 8 inches
Coal-bunker capacity	1,591.48 tons	1,355.2 tons	1,750 tons
Designed speed	16 knots	16 knots	17 knots
Actual speed	16.816 knots	17.013 knots	.....
Designed I.H.P.	10,000	10,000	10,000
Actual I.H.P.	11,674.3	11,073	.....
Designed revolutions	120	120	120
Actual revolutions	114	114.65	.....
Boiler pressure	180 pounds	180 pounds	265 pounds
Number of engines	2	2	2
Cylinders	33½, 51, 78	33½, 51, 78	25½, 42, 69
Stroke	48	48	48
Boilers	Scotch, cylindrical, double-ended	Scotch, cylindrical, single-ended	Water-tube
Total H. S., square feet	22,103.8	21,691.52	32,640
G. S., square feet	684	697.6	768
Air pressure	1.089	1.05	1.00
S. E. penalty weight	1,100 tons	1,130 tons	1,010 tons
Width armor belt	7 feet 6 inches	7 feet 6 inches	9 feet 3 inches
Material	Harveyized nickel-steel	Harveyized nickel-steel	.....
Thickness amidships	16½ in. top, 9½ in. bottom	16½ in. top, 9½ in. bottom	9 inches
Tapering at bow and stern to	4 inches	4 inches	4 inches
Triangular armor athwartship armored bulkheads	10 in. forward, 12 in. aft	12 inches	7 inches
Casemates	6 inches	5½ inches	7 inches

Superstructure armor	6 inches	5½ inches	.....
Barbettes (main)	15 in. front, 12½ in. rear	15 in. front, 10 in. rear	10 in. front and sides, 7½ in. rear
Main turrets	17 in. front, 15 in. rear	14 inches throughout	12 in. front, 8 in. sides and rear
Barbettes (for 8-inch guns)	.....	.....	6 in. front and sides, 4 in. rear
Turrets (for 8-inch guns)	11 in. front, 9 in. rear	.....	6½-in. front, 6-in. sides and rear
Conning tower	10 inches	10 in. forward, 6 in. aft	9 inches
Armor tube	7 inches	7 inches	.....
Protective deck	2¾ in. flat, 6¾ in. slope	2 ½-in. courses and 70-lb. steel, flat; 2 ½-in. courses and 80-lb. to 120-lb. steel, slope	2 ½-in. courses and 40-lb. nickel-steel, flat; 2 ½-inch courses and 100-lb. nickel-steel, slope
Main battery	4 13-inch B. L. R.	4 13-inch B. L. R.	.....
	.....	.....	4 12-inch B. L. R.
	4 8-inch B. L. R.	.....	8 8-inch B. L. R.
	.....	.....	8 7-inch B. L. R.
	.....	14 6-inch B. L. R.	.....
	14 5-inch B. L. R.	.....	.....
	4 torpedo tubes	4 torpedo tubes	2 torpedo tubes
Secondary battery	.....	.....	12 14-pdr. R. F., 3-in.
	20 6-pdr. R. F.	6 6-pdr. Hotchkiss	.....
	.....	10 6-pdr. Maxim	.....
	.....	.....	6 3-pdr. semi-automatic
	4 1-pdr. automatic	4 1-pdr. automatic	2 1-pdr. automatic
	4 1-pdr. R. F.	.....	2 1-pdr. R. F.
	.....	2 1-pdr. Hotchkiss	.....
	4 Colt automatic	4 Colt automatic	.....
	.....	.....	2 .30-cal. machine
	.....	.....	6 .30-cal. automatic
	2 3-inch field pieces	2 3-inch field pieces	2 3-inch field pieces

GENERAL DESCRIPTION.

The vessels and machinery are to be subject to the usual strict Government specification and rigid inspection.

The general dimensions and features of the vessel are as follows:

Length on load water line, feet	375
Breadth, extreme, at load water line, feet	77
Displacement on trial, not more than, tons	13,000
Mean draught to bottom of keel at trial displacement, feet and inches	24–8
Mean gross draught, full load, about, feet and inches	27–1½
Total coal-bunker capacity, about, tons	1,750
Coal carried on trial, tons	600
Feed water carried on trial, tons	40

The hull is to be of steel throughout, and docking and bilge keels will be fitted.

The armament will be as follows:

Main Battery.—Four 12-inch guns in pairs, in two electrically-controlled, balanced, elliptical turrets, on the center line, one on the upper deck forward and one on the main deck aft, with an arc of fire of about 270 degrees and 250 degrees, respectively.

Eight 8-inch guns in pairs, in four electrically-controlled, balanced, elliptical turrets, two on each beam, at each end of the superstructure.

Eight 7-inch guns in broadside, on pedestal mounts on the main deck, behind 7-inch armor, each pair of guns being isolated by transverse splinter bulkheads of nickel-steel 1½ inches thick; forward and after-guns arranged to fire right ahead and right astern, respectively; other 7-inch guns to have the usual broadside train. These 7-inch guns are so arranged that their muzzles train inside the line of the side armor, thus leaving a clear and unobstructed side when it is desired to go alongside a pier or vessel.

Secondary Battery.—Twelve 3-inch, 14-pounder, rapid-fire guns of 50 calibers in length.

Six 3-pounder semi-automatic guns.

Two 1-pounder automatic guns.

Two 1-pounder rapid-fire guns, heavy.

Two 3-inch field pieces.
Two machine guns, caliber .30.
Six automatic guns, caliber .30.

Armor and Similar Protection.—The hull is protected at the water line by a complete belt of armor, 9 feet 3 inches wide and of a uniform thickness of 9 inches, for about 244 feet amidships, forward and aft of which the belt is reduced in width and the thickness is gradually decreased to 4 inches at the stem and stern. Triangular athwartship armor in wake of water-line belt is 7 inches uniform thickness.

The lower casemate armor extends to the limits of the magazine spaces and reaches from the top of the water-line belt to the lower edge of the 7-inch gun ports on the main deck, and is 7 inches uniform thickness throughout, the athwartship armor bulkheads at the ends of this casemate being 7 inches thick.

The casemate armor around the 7-inch guns on the main deck is 7 inches thick and the splinter bulkheads are 1½ inches thick. The protection of 3-inch guns is nickel-steel 2 inches thick.

The upper casemate, diagonal and athwartship armor is to be 7 inches thick throughout.

The 12-inch barbettes extend from the main deck to about 4 feet above the upper deck and from the protective deck to about 4 feet above the main deck forward and aft, respectively, and consist of 10 inches of armor in front and sides and 7½ inches in the rear.

Between the main and protective decks forward there will be a uniform thickness of 6 inches.

The barbettes will not have any special framing, the connections of the armor to the decks being sufficient.

The 12-inch turrets will have a front plate 12 inches thick, rear and side plates 8 inches thick, and top plates 2½ inches thick.

The 8-inch barbettes will be 6 inches thick in front and sides and 4 inches thick in rear, with the upper tube 3¾ inches thick and the lower tube 3 inches thick.

The 8-inch turret front plate will be 6½ inches thick, and the rear and side plates 6 inches, and the top plates 2 inches thick.

The conning tower and shield will each be 9 inches thick. An

armor tube 36 inches in diameter will extend from the base of the conning tower to the protective deck, and will be 6 inches thick throughout.

The torpedo-directing stations will have 2½ inches of armor throughout.

Teak backing, of a minimum thickness of 3 inches, will be fitted behind all side armor, 12-inch turret armor, and diagonal and athwartship casemate armor on main deck aft; 2 inches of backing to be fitted behind the 8-inch turret armor; other armor will be fitted without backing.

Protective Deck.—There is a complete protective deck, extending from stem to stern, the deck being flat amidship, but sloped at the sides throughout and sloped at each end. It will be built up of 20-pound plating throughout, with nickel-steel of 40 pounds on the flat and of 100 pounds on the slopes.

Nickel-Steel Protection.—The following armor is of nickel-steel:

Upper strakes of protective-deck plating as indicated above; hatch covers and gratings in the protective deck; splinter bulkheads on main deck; sponsons and wing plates for two forward 3-inch guns on main deck; bullet-shields between wing plates for 7-inch guns; side-protection and wing plates for 3-inch guns on upper deck; turret-shelf plates; conning-tower base plates; 7-inch gun-port sill plates; 80-pound protection on ammunition-hoist trunks not otherwise protected by armor; and 80-pound protection on coaling trunks on slope of protective deck to the height of berth deck amidship.

Cofferdams.—Cofferdams, about 30 inches thick and extending from protective to berth-deck level, will be worked from end to end of the vessel, these cofferdams being extended above the berth deck forward and abaft the transverse armor, to a height of about 36 inches.

The cofferdams will be packed with cellulose or other approved water-excluding material.

Ammunition.—The magazines are so arranged that about one-half the total supply of ammunition will be carried at each end of the ship. Magazine bulkheads, adjacent to heated compart-

ments, such as fire rooms, engine rooms and dynamo rooms, will have air spaces.

The ammunition for 7-inch and smaller guns will be conveyed by hoists directly from the ammunition rooms or ammunition passages to the deck on which it is required. These hoists will be driven at constant speed by an electric motor, and will deliver about seven pieces per hoist per minute.

The number of hoists will be as follows: Eight 7-inch; eight hoists for 3-inch, 3-pounder and 1-pounder combined, and sufficient whip hoists to the top. To supply the 7-inch hoists, four horizontal ammunition conveyers, operated by electric motors, will be fitted in the ammunition passages for the transfer of ammunition from the handling rooms to the base of the hoists.

The turret guns have regular turret ammunition hoists, operated by electric power, leading directly from the handling room or the ammunition passages to the turrets. Trolleys and tracks will be fitted in the handling rooms, passages, shell rooms and other spaces, for transporting 12-inch, 8-inch and 7-inch ammunition, torpedoes and torpedo warheads.

Propelling Machinery.—The engines will be of the vertical, twin-screw, triple-expansion type, designed to develop 10,000 I.H.P., at about 120 revolutions per minute, with steam of 250 pounds pressure at the high-pressure cylinder. The cylinders are 25½, 42 and 69 inches diameter, with a common stroke of 48 inches. Each engine will be, as usual, in a separate watertight compartment. They are of the usual Bureau design, with open framing, the only difference for the later designs being that they have one low-pressure cylinder instead of two. Every effort has been made to keep the cylinder clearances as small as possible. The cylinders are entirely independent, and not secured to each other save by a tie rod in each side, connecting the three cylinders, and by athwartship tie rods between the two engines. There is one set of valve gear for each cylinder, and all valves are piston valves. The engines will be provided with all the necessary auxiliaries and accessories, in accordance with the latest practice of the Bureau of Steam Engineering.

There will be eight water-tube boilers, placed in four watertight

compartments. They will have not less than 768 square feet of grate and not less than 32,640 square feet of water-heating surface. The working pressure will be 265 pounds. The length of grates will be about 7 feet. The steaming capacity will be such that all steam machinery on board can be run at full power with an average air pressure in the fire rooms of not more than 1 inch of water. All parts of the boilers subject to pressure will be of wrought steel. There will be no screw joints in contact with the fire. No malleable or cast iron or cast steel will be used under pressure. Generating tubes will be straight and not less than 2 inches in diameter, without return bends or junction boxes. The tubes will be in groups of four or less, and will be expanded at their ends into two vertical or inclined wrought-steel headers, which will be sinuous in shape, for the purpose of staggering the groups of tubes. Each header will be provided with openings, placed opposite each end of each tube, of sufficient size to permit the inspection, cleaning, removal and renewal of a tube through the same. There will be a baffle plate parallel to the lower row of tubes, extending back from the front, and leaving at the back of the boiler sufficient area for the escape of the gases. There will be baffle plates in the boilers, so placed as to make the gases pass at right angles to the tubes.

All the necessary auxiliaries and accessories will be provided for the efficient working of the boilers.

There will be two funnels, each 100 feet high above the base line. Forty tons of fresh water will be carried on trial in the double bottom or in reserve tanks for use of the water-tube boilers.

The following auxiliary steam machinery of approved make and design, in addition to that pertaining to the main engines and dependencies, is to be supplied by the contractor and installed complete with all piping and fittings: Steering engine; windlass engine; ash-hoist engines for each fire room; forced-draft blowers; air compressor; dense-air ice plant with a cooling effect of 3 tons of ice per twenty-four hours; evaporating plant, to consist of not less than four units, having a total capacity of

16,500 gallons of fresh water per day; a distilling apparatus capable of condensing at least 16,500 gallons of water per day.

These auxiliaries are, in general, in accordance with modern practice. One new point, however, is the requirement that the refrigerating machine be driven by an electric motor. Another advance, and one which will no doubt be greatly appreciated by those having its operation in charge, is in the greatly increased capacity of the distilling and evaporating plant. This plant has been made the same size as that on the 16,000-ton battleships, and the distillers have been given the same capacity as the evaporators.

As in other ships recently designed, it is optional with the contractor to use rotary engines or steam turbines for the blowers, provided the steam consumption does not exceed 50 pounds per I.H.P. per hour.

There is the usual workshop and also a blacksmith shop.

Electric Plant.—The vessels will be lighted throughout by electricity. The electric plant will consist of eight 100-kilowatt steam-driven generating sets, all to be of 125 volts pressure at the terminals, disposed in two separate and independent dynamo rooms. Six electrically-driven generators for power to supply turret-turning motors; ten hundred and fifty electric fixtures, complete, with necessary incandescent lamps and outlets; ten inclosed arc lamps located in engine and fire rooms, as directed; five 30-inch searchlights mounted on platforms or bridges, with spare parts; one truck light, with controller and stand complete; one electric night-signalling set, complete, with spare parts; eleven signal lanterns; two diving lamps, with six outlets and eight incandescent lamps; six portable electric ventilating sets, $\frac{1}{4}$-horsepower, with spare parts; forty $\frac{1}{12}$-horsepower desk and bracket fans, with spare parts; eight $\frac{1}{8}$-horsepower bracket fans, with spare parts; one electric whistle operator; one set of running lights, complete; six cargo reflectors; also the necessary generator switch boards, main distribution boards, auxiliary and reserve distribution boards as may be directed for the efficient operation and control of the electric plant, together with the necessary wire, wiring accessories, wiring appliances, conduit

tubes and fittings, fixtures and lamps, and the instruments, tools, spare parts and stores usually furnished for the proper manipulation, test and repair of the plant.

There will be the usual means of interior communication, such as telephones, voice pipes, call bells, buzzers, gongs and annunciators, engine and steering telegraphs, revolution and rudder indicators, heeling indicators, automatic fire alarms, warning signals, alarm signals, etc.

With the exception of the auxiliaries before mentioned to be operated by steam, all power on board of the vessel will be electric, as, for instance, boat cranes, deck winches, turret turning motors, ventilation blower motors, etc.

All electric motors, for whatever purpose, will be supplied by the contractor, and the electric auxiliaries will be fitted in accordance with the specifications of the Bureau under whose cognizance they are furnished.

Ventilation.—All main compartments of the ship below the gun deck, except the coal bunkers, are to be provided with forced ventilation, there being not less than twenty-three blowers, with a combined capacity of not less than 114,300 cubic feet per minute. Special attention must be given to spaces subject to habitually high temperatures, such as engine rooms, fire rooms and dynamo rooms. The ventilation system will be designed to cut the minimum number of watertight bulkheads, and the blowers are to be electrically operated.

Coaling Arrangements.—The coal bunkers are to be arranged with satisfactory reference to the rapid and efficient supply of coal to the fire rooms and have a maximum capacity of about 1,750 tons. There are to be provided, for coaling, not less than six winches, twelve booms, and all necessary fixed chutes, scuttles, hatches and other openings.

Anchor Handling.—Complete arrangements are to be provided for the convenient handling and stowage of anchors. There will be two bill boards and four hawse pipes; there will be three heavy anchors of the Navy type and several small ones. Anchor davits, securing and tripping gear, controllers, ring bolts, riding-bitts, cleats, pad eyes, and other fittings will be provided.

Boats.—The following boats will be carried, adequate provision being made for their convenient stowage and handling, two electrically-operated boat cranes, eight pairs of boat davits, adjustable boat chocks, and all necessary fittings being provided for this purpose :

Two 40-foot steam cutters.
Two 33-foot sailing launches.
Four 30-foot cutters.
Three 30-foot whaleboats.
One 30-foot gig whaleboat.
Two 28-foot cutters.
Two 20 foot dinghies.
Four life rafts.

Complement.—The arrangement of quarters provides ample accommodations for the following complement, viz:

A commanding officer.
Fifteen ward-room officers.
Nine junior officers.
Nine warrant officers.
Not less than 686 men, including 60 marines.

Provisions, Clothing, etc.—Provision will be made for carrying not less than three months' allowance of provisions and six months' allowance of clothing and small stores.

Water System.—A complete drainage and flooding system will be provided, consisting of a main drain for engine and boiler rooms, secondary drain for all bilges, double-bottom drainage for all compartments within watertight longitudinals, and flooding for all compartments within machinery spaces and for trimming tanks. Sounding tubes will be fitted to all of the above double-bottom compartments and trimming tanks, and air escapes provided for such compartments as are to be flooded. There will also be installed magazine floods and complete fire system, with about fifty hose plugs; a flushing system for ready supply of salt water to all parts of the ship; also a fresh-water system for furnishing fresh water to all spaces required. The total quantity of fresh water carried in ship's tanks will be about fourteen thousand gallons.

Plumbing.—Plumbing fixtures to be in accordance with the latest approved practice for all bath rooms, lavatories, water-closets and other spaces.

Means of Handling and Navigating the Ship.—Steering appliances and other arrangements are such as have been found most satisfactory on latest vessels. Steering stations, with steam steering wheels, are located on the flying bridge, in the conning tower, in the communication room and in steering-engine room. Hand steering gear will be provided in the steering-engine room.

There is a lower bridge both forward and aft and a flying bridge forward, according to the latest practice. On the flying bridge is fitted a screen of bronze for the protection of the men at the wheel, and there is also a bronze chart house forward.

Masts.—There is a steel mast forward having an upper and lower top, and arranged for wireless telegraphy. There is one signal yard; also a searchlight platform and a crow's nest.

Wood Decks.—Exposed main deck, upper deck, bridge deck, top of charthouse and bridges will be planked; all planking to be of yellow pine, or teak if so desired by the contractor.

Deck Coverings and Joiner Work.—Floor coverings of linoleum or wood gratings will be fitted. All waterclosets, lavatories, wash rooms, laundry, bakery and similar spaces will be tiled. The quantity of woodwork will be reduced to the minimum, and no woodwork is to be fireproofed.

Sheathing.—All spaces in officers' quarters and both main and upper deck, bounded by the outer hull, also sick-bay dispensary, and other spaces, will be sheathed with metal backed with not less than 1½ inches of cork. Engine and fire-room hatch trunks on berth deck will be sheathed with asbestos fire felt and galvanized ceiling, or its equivalent. Asbestos sheathing will also be fitted over the engine rooms. Metal ceiling will be fitted to the outer hull in all living quarters not sheathed with non-conducting material.

The following is a summary of the weights to be carried:

Guns, torpedo tubes, mounts, magazine equipments, etc., tons.....	849.3
Ammunition, two-thirds full supply, tons.....	342.2

Steam engineering complete, with water in boilers, condensers, piping, etc., and stores, etc., not to exceed, tons	1,010
Engineering stores supplied by Government, tons	40
Reserve fresh water for steaming purposes, tons	40
Coal, normal supply, tons	600
Boats and outfits, tons	32.6
Masts and spars, tons	14.6
Equipment complete, including anchors, chains, electric plant, etc., and two-thirds equipment stores, tons	324.4
Miscellaneous stores and water, two-thirds full supply, tons	77.2
Provisions, clothing and small stores, two-thirds full supply, tons	124.8
Officers, crew and effects, tons	92.6
Total protection, including armor, armor backing, armor bolts, cellulose, and splinter bulkheads, tons	3,323

U. S. T. B. *TINGEY.*

GENERAL DESCRIPTION—CONTRACT TRIAL.

By Rear Admiral John D. Ford, U. S. Navy.

The *Tingey* is a twin-screw torpedo boat of 165 tons displacement, and was built by the Columbian Iron Works and Dry Dock Company, of Baltimore, Md., in conformity with a circular issued to builders, specifying the characteristics of sixteen torpedo-boat destroyers and twelve torpedo boats. This circular may be found on pages 817 to 825 of Volume 10, Number 3, of the Journal (1898.)

The vessel was built from the Navy Department's plans and specifications, the contractors submitting all drawings for the approval of the Bureaus concerned before work was commenced. The contract was signed October 1, 1898, the price being $168,000, and the time allowed for completion being twelve months. The price stated above does not include the ordnance, ordnance outfit and certain articles, as anchors and chains, which are supplied by the Government.

The speed guaranteed was 26 knots per hour, to be maintained successfully for two consecutive hours, to be run over a measured course. No premium for speed in excess of that required by the contract was provided for, but it was stipulated that a penalty at the rate of $12,000 per knot was to be inflicted in case the speed fell to 25 knots, and that the Secretary of the Navy should reject the vessel in case the speed could not be maintained at 25 knots. The weight of the machinery was limited to 80 tons, not to include the stores and spare parts supplied by the Government, steam-steering engine, steam windlass, dynamo engine and torpedo air-compressor machinery.

The penalty for overweight of machinery was $200 per ton over 80 tons, and if this overweight exceeded 5 per cent. of the

contract weight then $1,000 additional was to be deducted from the price of the vessel.

The vessel was successfully launched on March 25, 1901.

On January 17, 1902, representatives of the several contractors addressed a letter to the Navy Department in which they requested a modification of the requirements of the contracts for building said vessels, and for reimbursement for extraordinary expenses incurred by them in the fulfilment of said contracts. The Department approved the recommendation of the Bureaus, that each of said vessels be accepted as soon as it has passed a satisfactory trial as follows: "Standardization runs to be made up to the highest attainable speed of the vessel, these not to be considered satisfactory unless a speed of 28 knots is reached for all destroyers and 25 knots for torpedo boats. The Trial Board to be satisfied in each case that the vessels are properly run up to the highest speed attainable with due regard to efficiency and utility. After the standardization trials, the destroyers to make a satisfactory run of one hour at an average speed of at least 26 knots, and torpedo boats a satisfactory run of one hour at an average speed of at least 24 knots. The above requirements to apply to speed alone, and not to operate to change or modify the many other requirements of the vessels for acceptance. In case any vessel fails to make the speed herein required the case will be dealt with on its merits."

The time for completion was afterwards extended to December 15, 1903, for various reasons, the principal of which was the difficulty experienced in procuring material.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 18 inches apart, except in the engine compartments, where they are spaced to suit the engine bed-plate variations.

The thickness of the keel plate is 10 pounds per square foot for a length of 100 feet amidships; forward and abaft of this it is $7\frac{1}{2}$ and 9 pounds respectively. The vertical keel is 15 pounds per square foot and 8 inches deep. The outer plating is 7 pounds

per square foot; at the ends it is reduced to 5 pounds forward and 6 pounds at the stern.

The vessel is divided into ten watertight compartments:

First compartment, the trimming tank;

Second compartment, windlass and its engine;

Third compartment, officers' quarters—below the floor of quarters, stores and ammunition;

Fourth compartment, two boilers;

Fifth compartment, starboard engine room;

Sixth compartment, port engine room;

Seventh compartment, one boiler;

Eighth compartment, galley and crew's quarters;

Ninth compartment, crew's quarters;

Tenth compartment, quadrant room.

Coal Bunkers.—There are eight coal bunkers, four on each side of the vessel, with a total capacity of 72.72 tons at 43 cubic feet to the ton.

HULL DATA.

Length between perpendiculars, feet	175
on L. W. L., feet	175
over all, feet	175
Beam, extreme, feet and inches	17- 6
at L. W. L., feet and inches	16- 8
Ratio of length to beam	10.17 to 1
Beams to top of floor, feet and inches	11-10
Mean draught, seagoing trim, feet and inches	5- 4½
Displacement, seagoing trim, tons	215
per inch at L. W. L., tons	5.65
Area of immersed midship section, square feet	71
C. of G. of L. W. L. plane aft of midship section, feet and inches	10- 9
Center of buoyancy above bottom of keel, feet and inches	3- 5
aft of midship section, feet and inches	2- 9
Transverse metacenter above center of buoyancy, feet	6
Longitudinal metacenter above center of buoyancy, feet	550
Number of frames	115

BATTERY.

The battery consists of three 1-pounder semi-automatic rapid-fire Maxim guns and three Whitehead torpedo tubes, the compressor for which is of the Rand type V.

MAIN ENGINES.

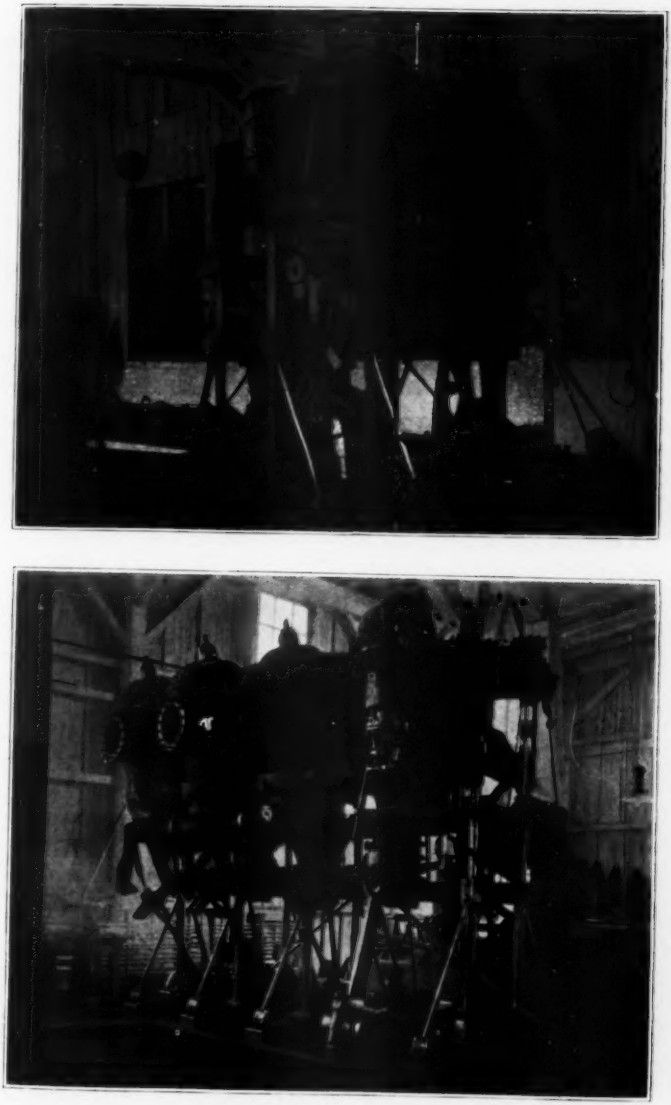
There are two vertical, inverted, direct-acting, triple-expansion, four-cylinder engines, placed in separate watertight compartments, the starboard engine forward and the port engine aft. In the cylinder arrangement the high-pressure cylinder of each engine is forward and the low-pressure cylinder aft. The cylinders are supported by vertical, forged-steel, cylindrical columns, stayed by forged and cast-steel ties and braces. Live steam may be admitted to both receivers. The main valves are of the single-ported piston type, there being for each engine, one for the H.P., one for the I.P. and one for each of the L.P. cylinders. The I.P. and L.P. main valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson link type, with double-bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from $\frac{5}{16}$ to $\frac{7}{16}$ of the stroke, by means of a block to which the suspension links are attached, which block can be moved by a hand screw geared in a slot in the end arm on the reversing shaft.

The main pistons are steel forgings, dished, and are fitted with two packing rings, each $\frac{5}{8}$ inch wide and $\frac{7}{16}$ inch thick. The piston rods, connecting rods and crossheads are of forged nickel-steel. The go-ahead sliding face of the crossheads is fitted with white metal. The ahead guide is of cast iron bolted to the engine-frame strongbacks, and is cast hollow for the circulation of water. Composition lips are bolted on each side of the ahead guide to take the thrust when backing. The eccentrics are forged on the shaft. The eccentric straps are of manganese-bronze faced with white metal, and the eccentric rods of forged nickel-steel. Each engine bedplate consists of separate girders, one under each bearing. The reversing engine consists of a steam cylinder with piston acting directly on an arm fixed on the reversing shaft. The valve of this engine is worked by a system of differential levers, the primary motion being derived from the hand lever at the working platform and the secondary motion from a point on the reversing arm. The turning gear consists of a worm wheel on the main shaft, which is worked by a hand ratchet.

Each engine is fitted with a single poppet, balanced stop valve, 5¼ inches diameter.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	14
I.P., diameter, inches	22
L.P. (2), diameter, inches	25¾
Stroke, inches	18
Valves, H.P., diameter, inches	7½
I.P., diameter, inches	14½
L.P. (2), diameter, inches	16½
Balance pistons, I.P., diameter, inches	4¾
L.P. (2), diameter, inches	4¾
Valve stem, H.P., diameter, inches	1⅝
through valve, inches	1¼
I.P. and L.P. (2), diameter, inches	1⅝
through valve, inches	1¼
Main steam pipe, to main engines, diameter, inches	5¼
from boilers, diameter, inches	4½
exhaust pipe to condenser (2), inches	9½
Piston rods, diameter, inches	3
length from piston to center of crosshead pin, inches	31 3/16
axial hole diameter, H.P. and I.P., inches	1 3/16
L.P., inches	2
Connecting rods, center to center, inches	40
H.P. and I.P., section at upper end, inches	1½ by 3¾
L.P., section at upper end, inches	1⅜ by 3
H.P. and I.P., section at lower end, inches	1 by 5
L.P., section at lower end, inches	⅞ by 4½
Crank-pin bolts (2), diameter, inches	1⅞
Crosshead pins, diameter, inches	3⅝
length of H.P. and I.P., inches	5¼
L. P., inches	4½
axial hole, diameter, inches	1½
H.P. and I.P., wearing surface, ahead, width, inches	7½
length, inches	11½
backing (2), width, ins.	2 3/16
length, ins.	13½
L.P. wearing surface, ahead, width, inches	6½
length, inches	11½
backing (2), width, inches	2 5/16
length, inches	11½



MAIN ENGINES, U. S. T. B. "TINGEY."

Cylinder diameters.	H.P. 14 in.	M.P. 22 in.	1st L.P. 25.25 in.	2d L.P. 25.25 in.
Common cylinder ratio	1:6.506	1:2.605	.....	.....
Net piston areas, average top and bottom, square inches	150.4	376.59	497.2	497.2
Volume of cylinders without clearance, cubic inches:				
Top	2,770.8	6,842.4	9,013.36	9,013.36
Bottom	2,643.6	6,715.17	8,886.11	8,886.11
Average	2,707.27	6,778.78	8,949.74	8,949.74
Volume of clearance, cubic in.:				
Top	772.37	1,487.09	1,728.72	1,728.72
Bottom	553.57	1,384.64	1,439.02	1,439.02
Average	662.97	1,417.86	1,583.82	1,583.82
Volume of cylinders with clearance, cubic inches:				
Top	3,543.17	8,329.49	10,742.08	10,742.08
Bottom	3,196.60	8,063.81	10,325.13	10,325.13
Average	3,369.88	8,196.65	10,533.60	10,533.60
Percentage of clearance:				
Top	27.87	21.72	19.17	19.17
Bottom	23.76	20.08	16.19	16.19
Average	24.48	20.91	17.69	17.69
Volumetric cylinder ratios, average, top and bottom	1:6.292	1:2.518	.....	.....

Shafting and Bearings.—The crank, thrust, stern-tube and propeller-shafting is hollow and of forged nickel-steel. The crank shaft of each engine is in one piece, with the eccentrics forged on. The cranks of the H.P. and I.P. are opposite, and the two L.P. are similarly placed with regard to each other. The H.P. and I.P. make an angle of 90 degrees with the first and second L.P., and the sequence of cranks is, therefore, H.P., first L.P., I.P. and second L.P. The forward end of the stern-tube shaft is supported by a spring bearing. The stern-tube shafts are covered with a composition casing from the forward to the after end of stern-tube bearing, projecting 1 inch outside of the bearing sleeves.

The coupling of the stern-tube and propeller shafts consists of a forged-steel sleeve 17 inches long secured by one key lengthwise and two cross keys.

Each thrust bearing is of the collar type, made of cast steel; it is water-jacketed, and is secured to the after girder of the engine bed plate by a 1½-inch diameter steel strut. The bearing

faces are white metal. There is an oil cup, common to all collars, the white metal being channeled for the distribution of oil.

Crank shaft, diameter, inches	6¾
axial hole, diameter, inches	4
coupling disc, diameter, inches	13½
thickness, inches	1⅝
straight coupling bolts (6), inches	1½
journals, diameter, inches	6¾
length (4), inches	8¼
(1), inches	4⅜
length, port, feet and inches	10– 4½
starboard, feet and inches	10– 7
Crank pins, diameter, inches	6¾
length, H.P. and I.P., inches	9
L.P., inches	7
Crank webs, width, inches	8
thickness, H.P. and I.P., inches	3
1st L.P., inches	3½
2d L.P., inches	3¾
Thrust shaft, diameter, inches	6
coupling disc, diameter, inches	13½
axial hole, diameter, inches	3¼
length, port, feet and inches	10– 4
starboard, feet and inches	22– 2
collars, number, each shaft	12
diameter, inches	8½
thickness, inch	½
space between, inch	1
Stern-tube shaft, diameter, inches	6
axial hole, diameter, inches	3¼
length, feet and inches	28–10½
Propeller shaft, diameter, inches	6
axial hole, diameter, inches	3
length, feet and inches	29– 0¾
Stern-bracket bearing, length, inches	18½
diameter, inches	6¾
tube bearings, length, forward, inches	21
aft, inches	21

Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate, No. 10 B.W.G., made of two plates formed to cylinders, butted together, secured by butt straps of Muntz metal, and stiffened with composition rings of tee section. The water chests are of copper, with tube

sheets of Muntz metal. The circulating water passes through the tubes. A baffle plate with slots is fitted the entire length of the condenser to direct the steam over the tubes. The inlet pipe is fitted with a circulating pump to act as a supplementary supply to the water forced through the condenser by the speed of the boat acting in a properly placed scoop.

Diameter of shell, inside, inches	37½
Thickness of shell	No. 10 B.W.G.
Tubes, diameter, outside, inch	⅝
length between tube sheets, inches	73½
thickness, No. 18 B.W.G., inch	.049
number in each condenser	1,236
Cooling surface, each condenser, square feet	1,240
total, square feet	2,480
Ratio total cooling to total heating surface	.317

Air Pumps.—For each engine there is a single-cylinder, double-acting, vertical, Bailey air pump. For the port engine the air pump is worked from an eccentric on the thrust shaft directly abaft that engine, and for the starboard engine the air pump is worked from an eccentric which is forged on the forward end of the starboard crank shaft. The eccentric rod gives motion to a rock shaft, to which arms are attached, and the latter are connected to the air pump crosshead by double bar links. A pump valve covers each end of the barrel, and the suction of the pump is through an annular opening at the center of the barrel.

Diameter of pump, inches	11
Stroke of pump, inches	6
Diameter of pump rod, inches	2
Diameter of rock shaft, inches	3½

Circulating Pump.—For each main condenser, there is one centrifugal, double-inlet, circulating pump, which is arranged to draw water from the sea and the bilges, and to discharge into the condenser as a supplementary supply. It is driven by an independent, vertical, single-cylinder engine.

Steam cylinder, diameter, inches	4
Stroke, inches	3
Pump runner, diameter, inches	18
Width at periphery, inches	1⅜
Inlet nozzle, diameter, inches	5½
Outlet nozzle, diameter, inches	5½

Screw Propellers.—The propellers are of manganese-bronze, tinned. They are true screws, bent back 9 inches at the periphery, the starboard left-handed and the port right-handed. They are of the modified Griffiths type. Each propeller is secured to its shaft by a single key and a composition nut screwed on and locked in place.

Number of blades	3
Diameter, feet and inches	5– 8
Length of hub, inches	13
Mean pitch, as set, feet	9.08
Greatest width of blade, inches	21⅞
Helicoidal area, each screw, square feet	10.3
Projected area, square feet	7.593
Disc area, square feet	25.22
Pitch ÷ diameter	1.29
Helicoidal area ÷ disc area	.408
Projected area ÷ disc area	.31
Weight of one propeller, complete, pounds	874

Boilers—There are three Thornycroft water-tubular boilers, of the *Speedy* type, located as follows: Two in the fourth compartment, forward of engines, and one in the seventh compartment, abaft the engines. In this type of boiler there is one steam drum situated at the apex of an equilateral triangle, and two water drums, one at each of the lower angles. The steam drum is connected to each of the water drums by a number of curved, solid-drawn, steel tubes for the generation of steam. The steam drum is also connected to the water drums by two down-take pipes, which are situated at the front of the boiler. The grate bars are of steel, in sections of six each, which are riveted together. The back and front of the furnace is formed up to the arch of the tubes with fire brick, and on each side to the joint of the tubes with the water drum; each boiler is bolted to angle irons, which are riveted to the saddles. The boiler is lagged with ½-inch thick sheet non-conducting material, protected by light steel plate, and put on in sections of such size as to be easily removed while the boiler is in place. There is but one furnace to each boiler, the shape of which is fixed by the arch of the tubes; there are three doors to each furnace. In the

steam drum is a Thornycroft automatic feed regulator, which is operated by the variation in the height of the water. The circulation of the water is up through the curved tubes to the steam drum, where the steam is liberated, and then down the large tubes to the water drum. Each boiler has two 3½-inch safety valves, placed on the stop-valve nozzles, both valves being in one case.

There is a fire extinguisher situated over each furnace for extinguishing fires on grates. There is a separate smoke pipe for each boiler.

BOILER DATA.

Steam pressure, designed, pounds	250
Number of boilers	3
Length of steam drum, feet	10
Width over casing, feet and inches	10– 8
Height, feet and inches	10– 4
Steam drum, diameter, inches	30
thickness, inch	¾
Water drums, diameter, inches	16
thickness, inch	⅝
Furnaces, width of grate, feet and inches	6– 9
length of grate, feet and inches	6– 9
Number of furnace doors	3
Tubes, diameter, inches	1⅝ and 1¼
number 1¼	776
1⅝	140
thickness	No. 11 B.W.G.
Heating surface of tubes, one boiler, square feet	2,516
Grate surface, one boiler, square feet	45.6
Ratio H. S. to G. S.	1 : 55.2
Total heating surface for the three boilers, square feet	7,548
grate surface for the three boilers, square feet	156.8
Smoke pipes (3), diameter (oval), inches	28 by 38
area, each, square feet	5.5
three, square feet	16.5
Height above lower grate, feet	20
Safety valves (2), diameter, inches	3½
Main stop valve, diameter, inches	4½

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by three blowers, made by W. D. Forbes & Co., two in the forward and one in the after boiler compartment. The blowers are driven by simple enclosed engines, set horizontally.

Cylinders (2), diameter, inches	4
Stroke, inches	3
Fan, diameter, inches	42
number of vanes	6
width at rim, inches	14
area of induction nozzle, square inches	706
eduction nozzle, square inches	1,847
Revolutions to maintain air pressure of 4½ inches	700

Feed Pumps.—There are three feed pumps, two main and one auxiliary, of the Davidson, vertical, single-cylinder type, all of the same size, 10 inches by 6 inches by 12 inches. The main feed pumps are located, one in the after engine room and one in the forward fire room, and draw their water from the feed tanks, the reserve feed tanks and air-pump suctions, and deliver to the boilers and reserve feed tanks. The auxiliary-feed pump is situated in the forward engine room, and draws water from the feed tanks, reserve feed tanks, the sea, the drainage system and boilers, and discharges into the boilers, the fire main and overboard.

Fire and Bilge Pumps.—In the after engine room there is a Davidson, vertical, single-cylinder pump, which draws water from the sea, the bilge or the drainage system, and delivers into the fire main or overboard. The steam cylinder is 6 inches, the water cylinder 6 inches and the stroke is 12 inches.

Water-Service Pump.—The distiller pump in the after fire room is used for this purpose. The water service can also be taken from the condenser.

Feed Tanks.—There is a feed tank of 64 gallons capacity in each engine room from which the water flows by gravity to the pumps. A part of the tank is fitted as a filter, into which water from the air pumps is delivered. The water descends through the filtering material and is discharged into the main portion of the tank; each tank has two hand holes and two glass water gauges. Each tank and filter has the following pipe connections: A discharge pipe from the air pump, an overflow pipe to the bilge, a suction pipe to feed pump, a vapor pipe, and a drain pipe from traps.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, steam-heating system and all places where con-

densed steam can accumulate are fitted with drain pipes and cocks, or valves, and with automatic traps, which discharge into the feed tanks. The traps are provided with by-pass pipes and valves.

Steam Ejectors.—There are steam ejectors of 2,000 gallons capacity per hour, one situated in each engine room and fire room, for the purpose of freeing the bilges of water.

Ash Ejectors.—There are two hydraulic ash ejectors, one fitted in each fire room.

Distilling Apparatus.—There are two evaporators and one distiller, of the Baird-Davidson type, located in the after fire room. These have a combined capacity of 2,000 gallons of potable water in 24 hours, at a temperature of 90 degrees Fahrenheit. The system is so arranged that steam for the distillers can be used from the auxiliary steam pipe in case of emergency. There is one distiller pump, $3\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by 4 inches stroke, and one evaporator pump, 3 inches by $1\frac{3}{4}$ inches by 4 inches stroke, both of the Davidson, vertical, single-cylinder type. The distiller has 12 square feet of cooling surface, and each evaporator 40 square feet of heating surface.

Steering Engine.—There is a combined hand and steam steering engine, made by the Hyde Windlass Company, of Bath, Me., located on the floor of the forward conning tower. The engine is of the horizontal type, with the wheel standard directly above it, the shaft of which connects with a pinion of the engine. The quadrant on the rudder is connected with the steering engine in the forward conning tower, and also with a hand-steering gear in the after conning tower, by means of a $\frac{5}{8}$-inch diameter wire rope. The engine has cylinders $3\frac{1}{2}$ inches diameter and $3\frac{1}{2}$ inches stroke.

Steam Windlass.—The steam windlass was built by the Hyde Windlass Company, Bath, Me., and is placed directly abaft the collision bulkhead. The engine is of the reversible, double-cylinder, horizontal type, and actuates the drums by means of a spiral gearing and pinion. The two drums, which are placed athwartships, are made for wire cable, and have a capacity of 75 fathoms of $\frac{9}{16}$-inch diameter wire rope. The engine cylinders

are 3¼ inches diameter and 4 inches stroke. The capstan on the turtle back is connected with the windlass below by means of a vertical shaft.

Air Compressor.—For charging the torpedoes there is one air compressor of the Rand V type, situated in the starboard engine room.

Telegraph and Revolution Indicators.—There is a Gibson and Kirk mechanical telegraph in each engine room, connected to transmitters in the forward and after conning towers; mechanical tell-tales are fitted in both engine rooms, to show the direction and number of revolutions of the main engines. In each engine room there is a mechanical revolution counter.

Voice Tubes.—There are voice tubes with electric call bells for communication between the conning towers, torpedo-tube stations and engine and fire rooms.

Electric Plant.—The installation consists of one 2½-kilowatt generating set, sixty incandescent lights, one searchlight, one set of signalling apparatus, one main switch board, together with the necessary wiring, wiring accessories, conduits and fixtures.

The generating set was made by the B. F. Sturtevant Co., and consists of one 2½-kilowatt dynamo of multipolar type with a capacity of 2 ampères at 80 volts, compound wound, 4 poles. The dynamo engine is of the single-cylinder, vertical type; diameter of cylinder, 3½ inches by 3 inches stroke. The engine is designed to run under full load at 800 revolutions per minute, with 100 pounds per square inch steam pressure. The bedplate is common to both engine and dynamo. The incandescent lights are of 5 and 16 candle power, designed for a potential of 80 volts. The dynamo is connected to the switchboard through suitable protected leads. The vessel is wired on the two-wire system.

There is one 12-inch hand-controlled searchlight, mounted on the forward conning tower and in circuit with a suitable rheostat mounted on the main switchboard.

Annunciators, press buttons and bells, are provided in connection with the speaking tubes for communication between the conning towers and the various compartments of the vessel.

MACHINERY WEIGHTS (IN TONS OF 2240 POUNDS).

Engine-room and stern weights	20.6209
Forward fire-room weights	25.4339
After fire-room weights	14.329

SUMMARY.

Engine-room and stern weights, with water	33.727
Fire-room weights	39.763
Total	73.490
Tools, stores, etc.	3.8886
Distilling and heating plants	2.0808
Total weight	5.9694

DETAILED WEIGHT FOR ONE ENGINE.

Cylinders and fittings	3.136
Shafting	1.827
Reciprocating parts	.785
Framing, bedplates and bearings	1.6379
Valves and valve gear	.7223
Condensers	1.7236
Air and circulating pumps	.6803
Boiler, fittings and uptakes (one boiler)	9.6437
Smoke pipe	.2585

FOR THE BOAT.

Steam, exhaust, suction, discharge pipes and valves	6.1821
Lagging and clothing	3.6892
Floor plates	1.1696
Auxiliaries	3.0598
Fittings and gear	2.0486

THE TRIALS.

The official trial of the *Tingey* was held on the Barren Island Course, Chesapeake Bay, Maryland, on October 12, 1903: The Trial Board went on board the *Tingey*, and proceeded in her to the trial course. The wind was moderate to fresh from N. N. W., with moderate sea. The vessel was in charge of Mr. H. Konitzky, who represented the contractors, while the engineers and firemen, all experienced in this class of work, were under the supervision of Mr. H. D. Haverfield. At 10·00 A. M. the standardization runs were commenced and finished at 11·08 A. M., from which the following data were obtained.

TABLE I.—DATA OF THE STANDARDIZATION RUNS OF TORPEDO BOAT No. 34, THE *TINGEY*, OVER THE BARREN ISLAND, ONE-KNOT COURSE, CHESAPEAKE BAY, OCT. 12, 1903.

No. of runs.	Direction.	Time over course.	Revolutions of the engines per knot.		Knots per hour.	Steam pressure.						Vacuum.		Air pressure in inches.	
						H.P.		M.P.		L.P.					
			S.	P.		S.	P.	S.	P.	S.	P.	S.	P.	A.	F.
		m. s.													
1	S.	2 53.7	876	861	20.725	145	140	55	50	2	-2	26	26	$1\frac{8}{8}$	$\frac{7}{8}$
2	N.	2 52.1	882	867	20.918	155	155	60	60	4	0	25.8	26.2	$1\frac{8}{8}$	$1\frac{1}{8}$
3	S.	2 37.8	867	855	22.814	180	180	60	60	5	2	25.5	26	1.83	$1\frac{8}{8}$
4	N.	2 41.2	879	869	22.333	170	160	60	58	4	1	24	24	1.83	$1\frac{8}{8}$
5	S.	2 31.6	870	845	23.747	210	205	75	70	7	5	23.5	23.8	4.9	$1\frac{8}{8}$
6	N.	2 33.7	877	861	23.422	205	205	78	75	9	7.5	23.5	24	6.66	$1\frac{8}{8}$
7	S.	2 21.4	882	850	25.46	245	240	83	85	11	9.5	21.5	22	7	2.99
8	N.	2 27.4	896	859	24.423	240	235	68	76	9	7	20.5	21	$7\frac{8}{8}$	5.08

Draught at beginning of trial, forward, feet and inches	5- $\frac{8}{4}$
aft, feet and inches	5- $2\frac{8}{4}$
mean, feet and inches	5- $1\frac{8}{4}$
end of trial, forward, feet and inches	4-$10\frac{1}{2}$
aft, feet and inches	5- $2\frac{1}{2}$
mean, feet and inches	5- $3\frac{3}{16}$
Displacement at beginning of trial, tons	193
end of trial, tons	186
Coal consumed during the trial, Pocahontas, hand picked, lbs.	11,600

For standardizing the propellers the several double runs were made as nearly as practicable at the rates of speed prescribed by the precept for the trial. At a signal given by the observer, who marked with a stop watch the time of passing the range marks placed at the end of the course, the counter was thrown into gear at the moment of entering and out of gear at the moment of leaving the course. Readings of the engine-room gauges were taken and recorded during each run.

Average number of revolutions for one hour, both engines, 348.4, which corresponds to a speed of 24.12 knots.

The result of the runs with and against the tide were plotted as separate curves from which the true speed was obtained, which showed that a mean of both engines of 346.3 revolutions was requisite for a true speed of 24 knots.

TABLE II.—ONE HOUR ENDURANCE TRIAL U. S. TORPEDO BOAT *TINGEY*, OCT. 12, 1903.

Time. 2'24	Boiler steam, pounds square inch.	Main steam at engines, lbs. sq. in.		1st rec. gauge, lbs. sq. in.		2d rec. gauge, lbs. sq. in.		Vacuum in inches.		Temperature of feed, F.°		Temperature of discharge, F.°		Temperature of injection, F.°	Temperature of engine room, F.°	Counter.	Revolutions per minute.	Air pressure in inches.	
		S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.					For'd	Aft.
2'29	250	240	235	80	80	10	7	22.5	23	145	145	114	113	75	100	S., 1,745 P., 1,715	349.0 343.0	3.75	4.75
2'34	210	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S., 3,503 P., 3,440	351.6 345.0	4.00	4.75
2'39	245	230	230	82	72	11	5	22.5	23	155	150	115	115	75	100	S., 5,245 P., 5,151	348.4 341.8	..	...
2'44	225	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S., 7,013 P., 6,894	353.6 348.6	4.00	4.50
2'49	240	245	250	77	85	9.5	9	21.5	22	157	155	120	118	75	100	S., 8,765 P., 8,623	350.4 345.8	...	...
2'54	250	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S., 10,545 P., 10,370	356.0 349.4	1.625	4.75
2'59	250	250	250	80	87	10	9	21.5	22	157	155	120	118	75	100	S., 12,274 P., 12,084	345.8 342.8	...	...
3'04	250	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S., 14,103 P., 13,875	365.8 358.2	1.875	4.25
3'09	245	245	245	80	85	10	8	21.5	22	160	156	120	118	76	100	S., 15,853 P., 15,605	350.0 346.0	...	...
3'14	245	240	247	80	85	9	8	22	22.5	157	155	120	118	76	...	S., 17,593 P., 17,329	348.0 344.8	1.875	4.25
3'19	245	240	245	77	83	9	8	21.5	22.2	157	150	120	115	76	100	S., 19,310 P., 19,038	343.4 341.8	...	...
3.24	225	225	230	80	80	10.5	7	21.5	22	150	152	115	112	76	...	S., 21,050 P., 20,760	348.0 344.4	1.875	4.50

A mean speed of 24.9415 knots was made during one double run.

After finishing the standardization runs, the *Tingey* returned to Solomon's Island where she was re-weighted for the one hour's endurance run, which was commenced at 2·24 P. M., with the result as shown on page 65.

Draught at beginning of the one hour trial for'd, feet and inches...	5- 0¼
aft, feet and inches.....	5- 2½
mean, feet and inches..	5- 1 3/16
end of the one-hour trial forward, feet and inches.....	4-10
aft, feet and inches.....	5- 2
mean, feet and inches.....	5- 0
Displacement at beginning of trial, tons.....	190.5
end of trial, tons.....	184.
Coal consumed during the one-hour trial, Pocahontas, hand-picked; pounds.....	14,500

No indicator diagrams were taken from the engines during either of these runs.

After the one-hour endurance trial, the tactical diameter was taken and was estimated to be 350 yards. The angle of heel was about 7 degrees. This diameter was taken at a speed of about 24 knots. The time taken to put the helm from amidships to hard-a-starboard was 8 seconds, and from hard-a-starboard to hard-a-port 13 seconds.

The vibration of the vessel as a whole while under way was moderate.

The boilers steamed freely and the machinery ran smoothly and well. An examination of the engines and boilers after the trial showed them to be in good condition.

The trials were conducted by the Naval Board of Inspection and Survey, composed of Captain C. J. Train, U. S. N., President; Captain L. C. Logan, U. S. N., Naval Constructor J. J. Woodward, U. S. N., Commander W. C. Cowles, U. S. N., and Lieutenant Commander W. Strother Smith, U. S. N., members; and Lieutenants H. V. Butler, U. S. N., and H. C. Dinger, U. S. N., assistants to the Board.

THE U. S. S. *DENVER.*

GENERAL DESCRIPTION.—OFFICIAL TRIAL.

By Commander W. H. Naumann, U. S. N., Member.

The *Denver* is a twin-screw protected cruiser of 3,200 tons displacement, built by the Neafie and Levy Ship and Engine Building Company, of Philadelphia, and is one of the six vessels of this class authorized by the Act of Congress approved March 3, 1899, the others being the *Des Moines*, *Chattanooga*, *Galveston*, *Tacoma* and *Cleveland*. The general plans and specifications were furnished by the Navy Department, but the development of details and arrangement and location of auxiliary machinery and piping were made by the contractors. All drawings, however, were submitted to the Navy Department for approval before the work was begun.

The contract for the *Denver* was signed December 14, 1899, the price being $1,080,000, and the time allowed for completion thirty months from date of contract.

A ten months' extension of the time for completion was allowed the contractors because of the difficulty experienced in the delivery of material. The price stated above does not include the ordnance and equipment. The guaranteed speed was 17 knots per hour (which is one-half knot more than the five other vessels of the *Denver* class) to be maintained successfully for four consecutive hours, the air pressure in the ash pits not to exceed an average of one inch of water, the vessel to be weighted to a mean draught corresponding to a trial displacement of 3,200 tons. If the speed fell below 17 knots, the contract inflicts a penalty at the rate of $25,000 per quarter knot for speeds between 17 and 16½ knots, and $50,000 per quarter knot for speeds between 16½ and 16 knots.

HULL.

Length between perpendiculars, feet	292
over all, feet and inches	308- 9½
of L.W.L. (normal), feet	292
Beam, extreme, feet	44
at L.W.L., feet	44
Ratio of length to beam, L ÷ B	6.6364
Depth (molded) from top of main-deck beams at side to bottom of frame at midship section, feet and inches	30- 3
Draught, normal, mean, feet and inches	15- 9
Displacement corresponding to normal draught (salt water), tons,	3,196
per inch at L.W.L., tons	22.3
Area of midship section, square feet	607.5
of L.W.L., plane, square feet	9,376
Center of gravity of L.W.L. plane aft of midship section, feet and inches	3-10½½
Center of buoyancy above bottom of keel, feet and inches	9- 2¼
aft of midship section, inches	9
Transverse metacenter above center of buoyancy, feet and inches	10-00¼
Longitudinal metacenter above center of buoyancy, feet and inches	280- 9½
Coefficient of fineness of midship section	.876
L.W.L.	.730
(prismatic coefficient)	.630
Coefficient block	.55
Wetted surface, square feet	14,817
Number of frames	100
Number of watertight compartments	174

The hull is constructed of mild steel of domestic manufacture with frames spaced 36 inches apart throughout the length of the vessel. Frames from No. 18 to 86, inclusive, are of Z bars 6 by 3½ by 3½ inches, from No. 17 bulkhead forward and from No. 87 aft, the frames are of 4 by 3½-inch angle bars. The flat keel plates are continuous from the stem to forepart of sternpost, the inner course being 32 inches wide of 15-pound plate, and the outer course 42 inches wide of 20-pound plate. The vertical keel is 34 inches in depth, except at ends, of 15-pound plate. The inner bottom extends from frame 17 to 85, inclusive. A cofferdam 27 inches wide is constructed between berth and protective decks, extending from sternpost forward to bulkhead No. 7, and is filled with fireproofed corn-pith cellulose. Transverse bulkheads divide the cofferdams into numerous watertight com-

partments. The shell plating is planked with Georgia pine from the keel to 42 inches above the water line amidships, sheering up forward to 69 inches and aft to 51 inches. The planking is 4 inches thick except at about 20 feet abaft the stem and forward of the sternpost, where it is reduced to $3\frac{1}{2}$ inches. Between the planking and the steel plating thick red-lead paint was injected under pressure. The planking is secured to the hull by $\frac{7}{8}$-inch naval-brass screw bolts screwed through the plating, with nuts on inboard ends. From 3 inches below the upper edge of the wood planking the vessel is copper sheathed. Of this surface to be coppered, the upper section, 22 per cent., is covered with 30-ounce sheathing copper; the middle section, 44 per cent., is covered with 28-ounce sheathing copper; the bottom section, 34 per cent., is covered with 26-ounce sheathing copper.

The main deck is covered with fine-grained Georgia pine, $3\frac{1}{2}$ inches square, cut to lay "vertical grain," and secured to the steel deck with $\frac{3}{4}$-inch galvanized-iron bolts.

On the main deck are located the main-deck cabin, chart house and deck winches.

On the gun deck are located the captain's cabin, state room, office, pantry and bath room, executive officer's state room, and office, navigator's state room and office, paymaster's office, sick bay and bath, dispensary, armory, engineer's office, lamp room, crew's wash room and water closets. Foward there is berthing space for the crew.

On the berth deck aft are located the ward room officers' and warrant officers' quarters. On this deck are also the engineer's work shop, ice machine and refrigerating rooms, forced-draft blower rooms, crews' berthing space, machinists' and firemen's wash rooms, and upper coal bunkers. Below the protective deck are the engine and boiler rooms, steering-engine and dynamo rooms, coal bunkers, store rooms, trimming tanks, magazines, shell rooms, holds and chain lockers.

There are nineteen coal bunkers with a total capacity of 712.60 tons at 43 cubic feet to the ton. Trolleys and buckets are fitted in the fore and aft outboard bunkers B-4 and 5, B-8 and 9, and C-3 and 4.

Steam fire-extinguishing pipes are fitted in all coal bunkers. The bunker ventilation consists of both the supply and exhaust systems.

VENTILATION.

The system of ventilation is divided into a larger number of units of a smaller size than is the usual practice.

The advantages gained in this arrangement over the old one of a small number of large units are:

(1) That a less number of watertight bulkheads need be pierced and fewer bulkhead valves used.

(2) A reduction of horsepower required to drive the fans.

(3) Less frictional resistance, owing to shorter lengths of piping.

(4) The use of smaller ducts, requiring less space.

(5) The disabling of any one unit would inconvenience a smaller number of the ship's compartments.

The spaces above the protective deck and a few connected compartments below the same are ventilated by the "exhaust" system, the remaining compartments by the "supply" system, except the dynamo room and steering-engine room, which have both systems.

Eight fans are used in the "supply" system and eight in the "exhaust" system, all driven by individual motors connected direct to the fan shaft.

BOATS.

The following boats are carried on board:

One 30-foot steam cutter.

One 30-foot sailing launch.

Four 28-foot cutters.

One 28-foot gig whaleboat.

One 28-foot whale boat.

One 20-foot dinghy.

One 16-foot dinghy.

Drainage System.—The main drain is of galvanized steel, 10 inches in diameter, and runs through the fire and engine rooms, having branches in each engine room connecting it with each main circulating pump.

It is also provided with connections to the fire and bilge pumps in each engine room, and to the auxiliary feed pumps in the fire rooms. It has also indirect connections with the auxiliary drain in the engine and fire rooms.

The auxiliary drain is a 5-inch pipe, running above the inner bottom from bulkhead 24 aft into the starboard-engine room, where a branch connects to the fire and bilge pump, and another branch leads across to the fire and bilge pump in the port-engine room. Manifolds are conveniently located with suction pipes leading to all double bottoms, hold compartments, and to fire-room bilge wells.

Independent drain pipes in each fire room drain the fire-room bilge wells and wing coal bunkers through the fire-room bilge pumps. The drainage of water from bridges, chart house and main deck is effected by scuppers which discharge from the ship's side, above the water line. The gun and berth decks are drained by deck drains, where necessary, leading to scupper pipes.

Water from the dynamo room is carried off by a pipe into the forward fire-room bilges.

Flooding.—Separate sea valves, operated from the berth deck, flood all magazines. All double-bottom compartments are fitted so that they can be flooded from the sea.

ARMAMENT.

The main battery consists of ten 5-inch breech-loading rifles, 50 caliber, Q. F. mark V, two located on the main deck, one forward and one aft. The remaining eight are located on gun deck, four on a side.

The secondary battery consists of eight 6-pounder rapid-fire guns, two 1-pounder rapid-fire guns, and four Colt automatic, .30 caliber machine guns. The four Colt automatic and four of the 6-pounders are located on the main deck. The remainder of the secondary battery is on the gun deck.

Ammunition Hoists.—Ten ammunition hoists, operated by electric motors, are conveniently located for handling the ammunition for the guns.

MAIN ENGINES.

Cylinders.—There are two four-cylinder, triple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments, and arranged for inboard-turning screws. The arrangement of cylinders, beginning forward, is forward low pressure, high pressure, intermediate pressure and after low pressure. All cylinders are steam-jacketed around the working liners.

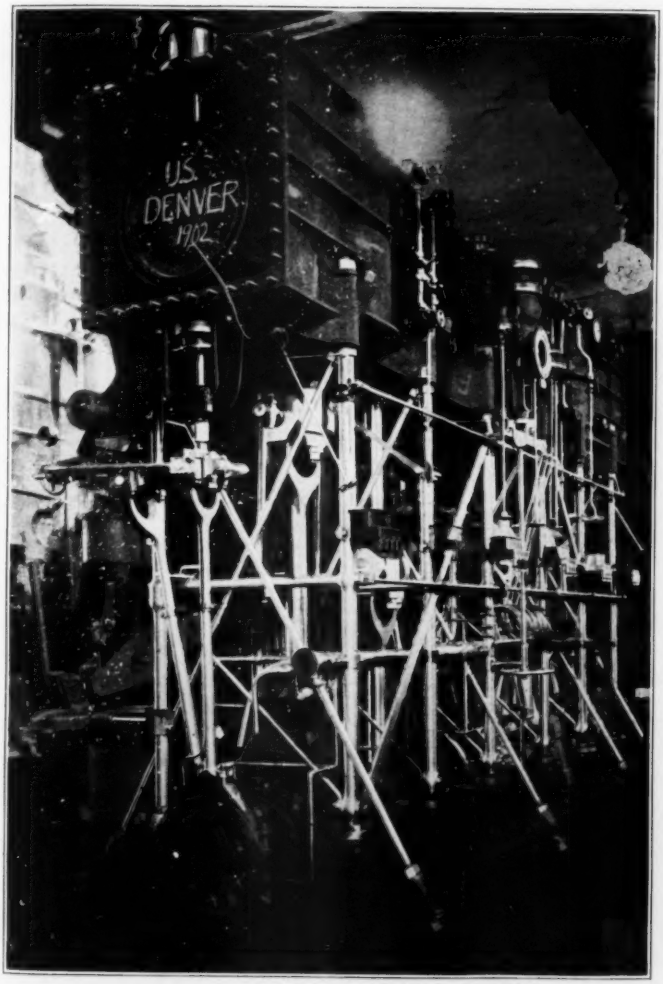
Framing.—The cylinders are supported by twelve forged-steel columns, stiffened by fore-and-aft and athwartship horizontal and diagonal tie rods, all of forged steel. At the back of the engine a strongback of cast steel is bolted to columns, acting in a double capacity of stiffener for columns and support for lower ends of crosshead guides. The engines are further stiffened by diagonal tie rods secured at top to lugs cast on the cylinders, and at the bottom to lugs cast on the bed plates.

Valves.—The valve chest of each high pressure cylinder is fitted with one, each intermediate-pressure with two piston valves, and each low-pressure with one double-ported slide valve. The valves are all provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests.

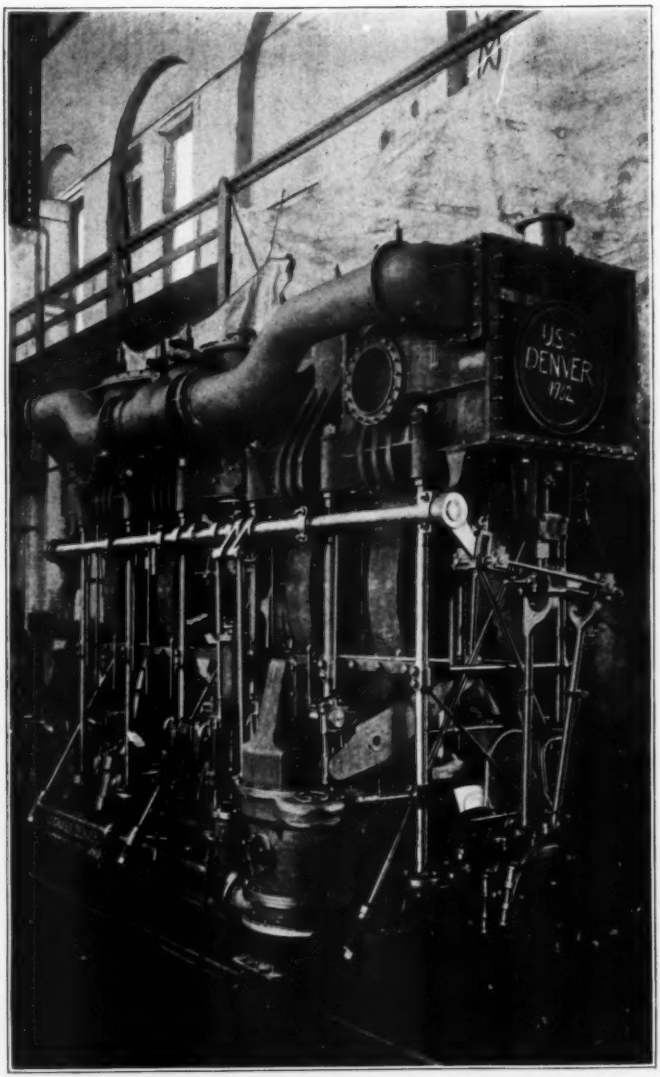
Valve Gear.—The engines are fitted with Stephenson double-bar link motion, and have adjustable cut-offs actuated by screws in slotted arms on the reverse shafts. The eccentrics are of cast iron. The eccentric straps are of composition, lined with Government standard white metal, and the eccentric rods are of high-grade machinery forgings.

Throttle.—Each engine has a 6½-inch throttle valve, balanced by a piston working in a cylinder forming part of the throttle-valve casing, steam being admitted to the back of the balance piston.

Pistons, Rods and Crossheads.—The steam pistons are of cast steel, conical in shape, each fitted with a packing ring and follower. The piston rods are of nickel-steel forgings, with crossheads forged on and axial holes running the entire length of the rod. The crosshead slippers are of manganese-bronze, lined on both the ahead and astern faces with white metal.



MAIN ENGINE, "DENVER." FRONT VIEW.



MAIN ENGINE, "DENVER." BACK VIEW.

Connecting Rods.—The connecting rods are of forged nickel-steel with axial holes the entire length. The crosshead end is forked to span the crosshead, the crosshead pin being shrunk in and secured.

Guides.—The crosshead guides are of cast iron and made hollow for the circulation of cooling water. At the top they are bolted to lugs on the steam cylinders, and at the bottom to cast-steel strongbacks bolted to engine columns.

Bedplates.—The bedplates are of cast steel, each in three sections, with flanges for bolting together. Each section consists of two longitudinal girders of ∩ section and two cross girders of I section, with stiffening ribs. This bedplate carries the crank-shaft bearings.

Shafting.—All the crank, line, thrust and propeller shafts are forged steel with axial holes through them. The crank shafts are made in two sections, with two cranks on each section, placed opposite each other. The forward low-pressure and high-pressure cranks are opposite, also the intermediate and after low-pressure cranks, the second pair being at right angles with the first, the sequence of the cranks being, high-pressure, intermediate-pressure, forward low-pressure and after low-pressure.

Casing.—The stern-tube and propeller shafts are covered with cast composition watertight casing, put on in sections, shrunk and pinned on.

Thrust Bearings.—The thrust bearings are of the horseshoe pattern. The pedestals are of cast iron and horseshoes of cast steel lined with white metal.

Shaft Bearings.—The propeller shafts are each supported by two outboard strut bearings; the stern-tube shafts by bearings at each end of stern tubes, and line shafts by three spring bearings. The stern-tube and strut bearings are lined with lignum-vitae, end grain exposed, while the spring bearings are lined with white metal in lower half of bearing only.

Reversing Gear.—The reversing gear for each engine consists of a steam cylinder and oil-controlling cylinder, acting on arms fixed on the reversing shaft by means of connecting links. A hand pump is provided, connected with the oil cylinder for reversing by hand.

Turning Engine.—The turning engine is a double, inverted engine, driving a worm shaft, which in turn drives a second worm made to mesh at will with a worm wheel on the coupling flanges between the two sections of crank shafts. A ratchet wrench is fitted for turning the gear by hand.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	18
I.P., diameter, inches	29
L.P. (two), diameter, inches	35½
stroke, inches	30
Valves, H.P. (one piston valve for each cylinder), diameter, inches	11½
I.P. (two piston valves for each cylinder), diameter, inches	11½
L.P. (one double-ported slide for each cylinder), inches, length, 28 5/8; width, 39½; length of ports	37
Valve stems, H.P. (one), diameter, inches	2
I.P. (two), diameter, inches	2
L.P. (two), diameter, inches	2½
Main steam pipe, diameter, inches	6½
Exhaust pipe to condenser, diameter, inches	14
Piston rods, diameter, inches	4½
axial hole, diameter, inches	2
Connecting rods, section at upper end, diameter, inches	4⅜
lower end, diameter, inches	4⅞
axial hole, diameter, inches	2
center to center, inches	67
Crank-pin bolts (two), diameter, inches	2½
Crosshead pins, diameter, inches	5½
length, inches	10
axial hole, diameter, inches	2½
Crossheads, wearing surface, ahead, inches	12 by 14½
backing (two), inches	4⅞ by 14½
Crank shaft, diameter, inches	9½
axial hole, diameter, inches	5
coupling flange, diameter, inches	17
thickness, inches	2½
Crank shaft, coupling bolts (six), diameter, inches	2
journals, diameter, inches	9½
(four), length, inches	11
(one), length, inches	12½
(one), length, inches	18
pins, diameter, inches	9½
length, inches	11
webs, width, inches	10½

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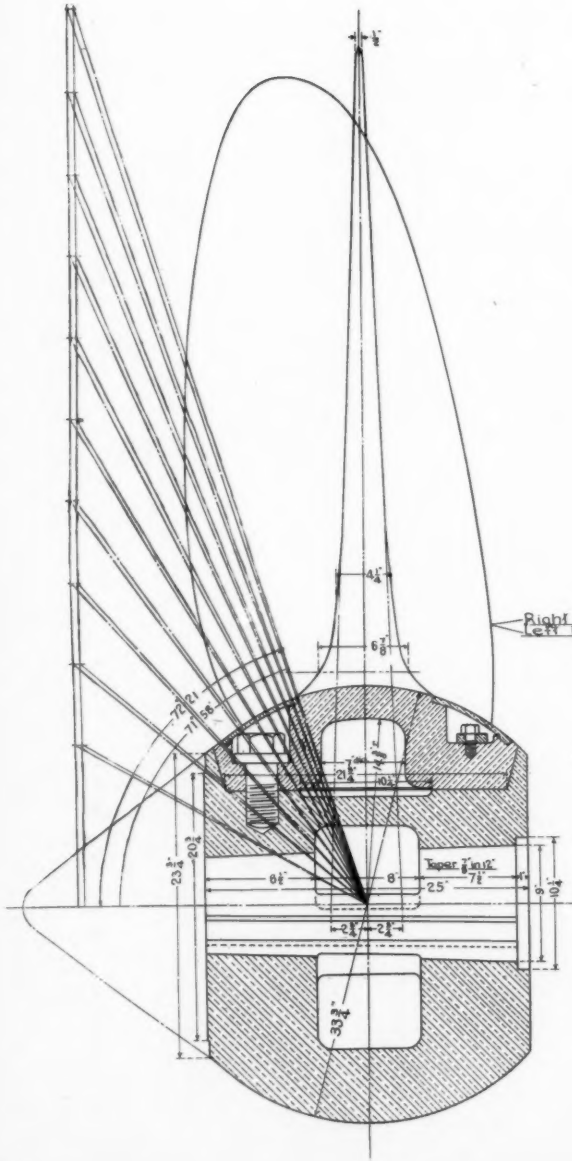
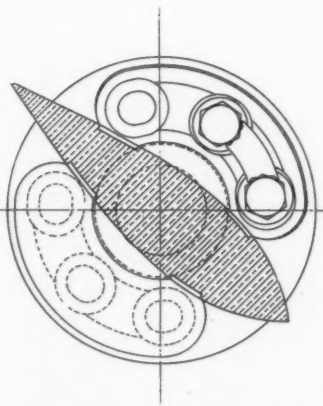




U. S. S. Denver.

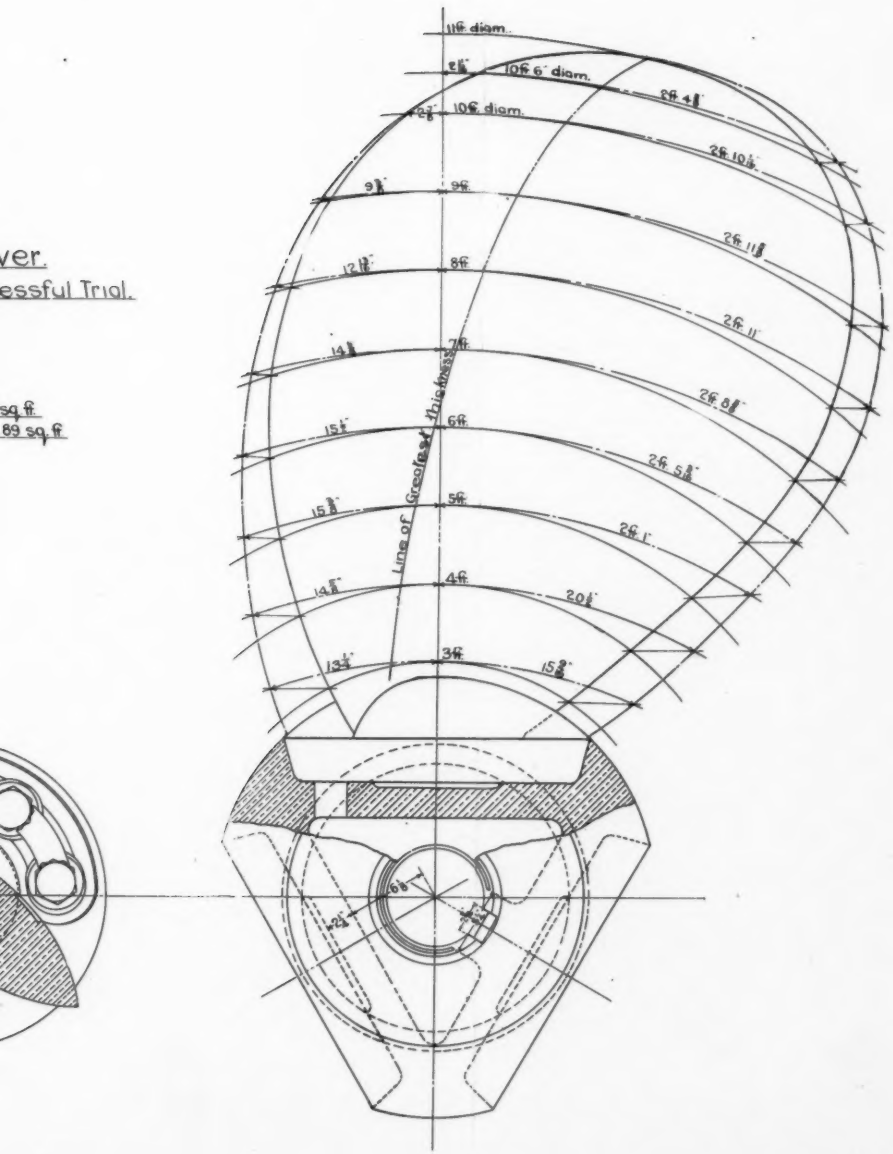
Propeller used on unsuccessful Trial.
Oct. 22. 1903.
Scale 3"=1ft.

Diameter	11ft-0"
Pitch	11ft-0"
Projected Area	36 sq ft
Developed Area	40.89 sq ft
Pitch ratio	1.
Proj. Area / Dev. Area	= 881
Proj. Area / Disc Area	= .379

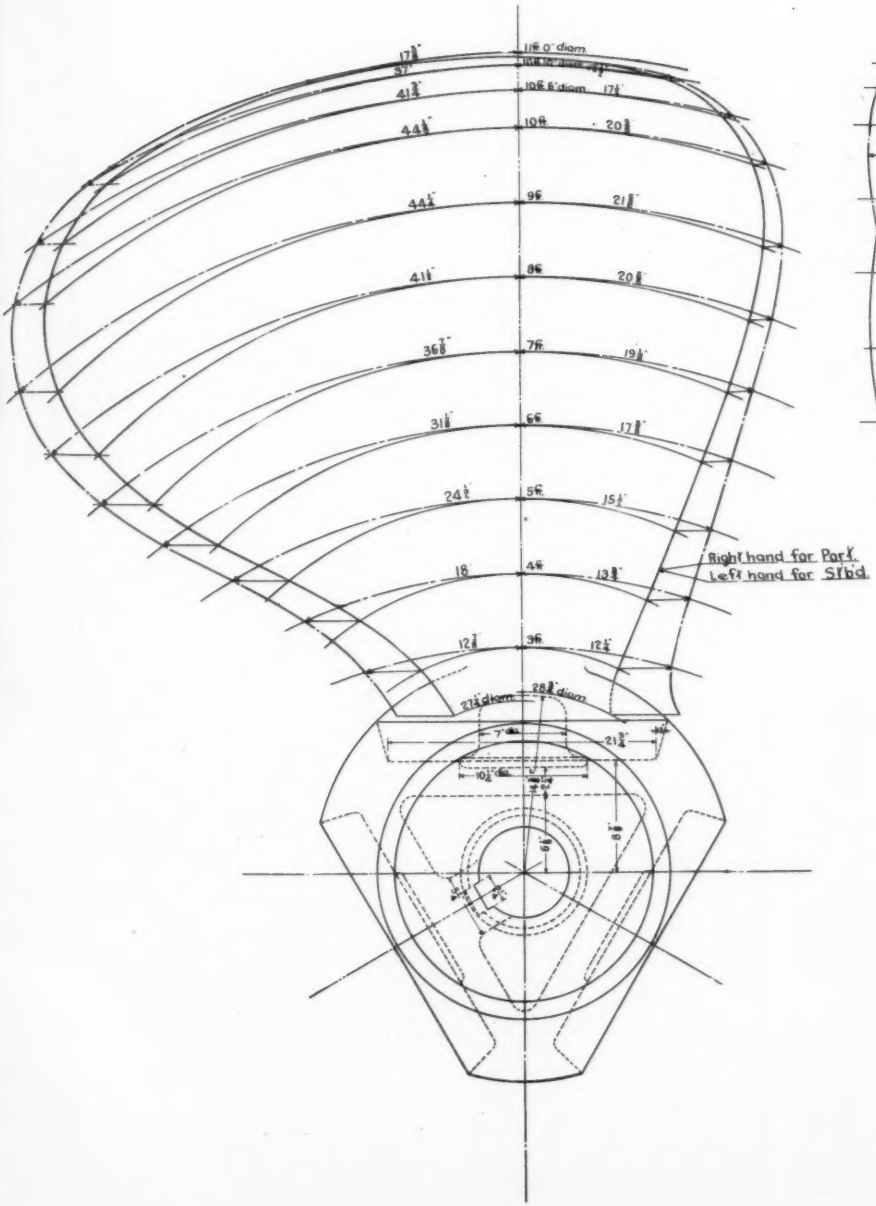
Fig. 1.

ver.
essful Trial.

sq ft
89 sq ft



g. 1.


Right hand for Port.
Left hand for Stbd.

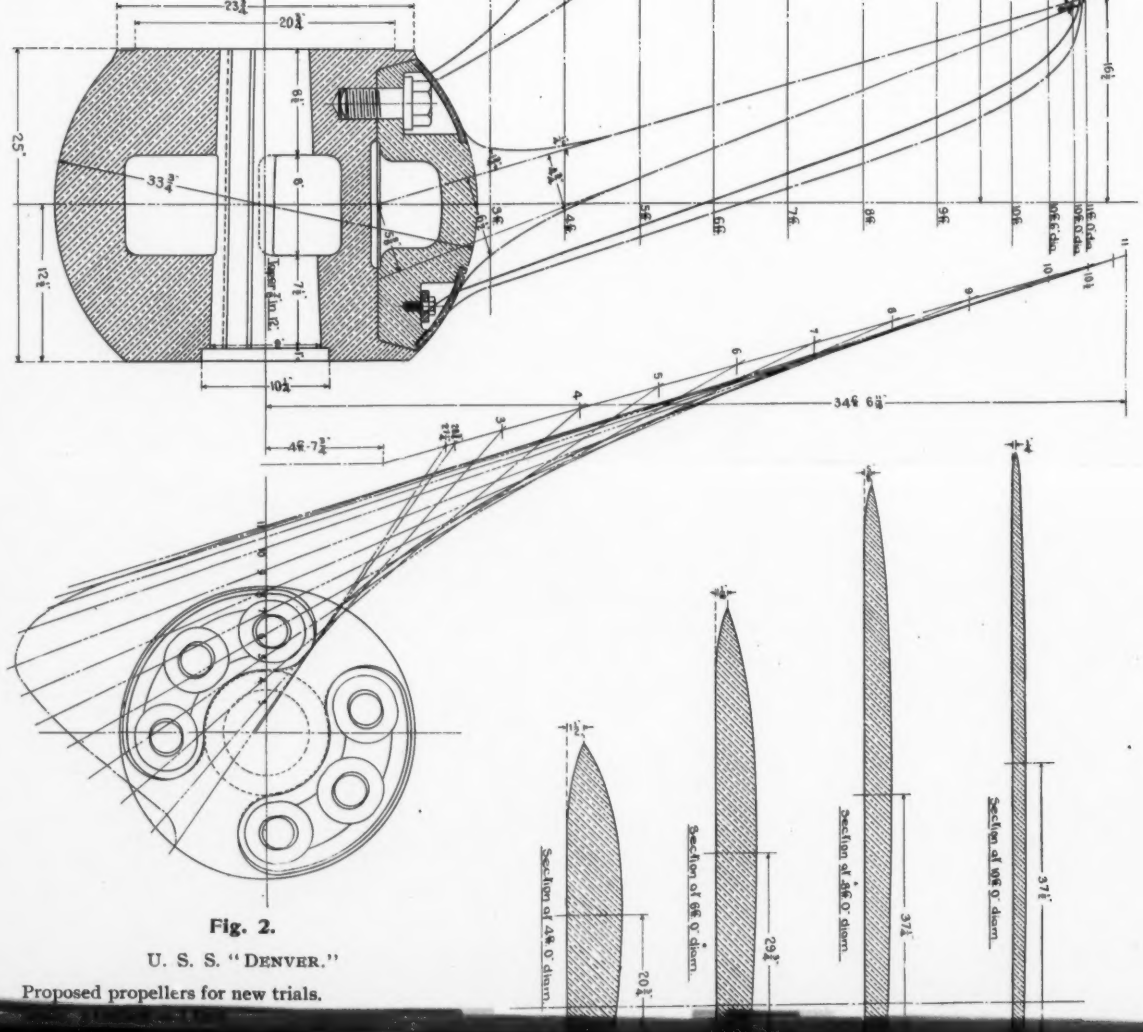
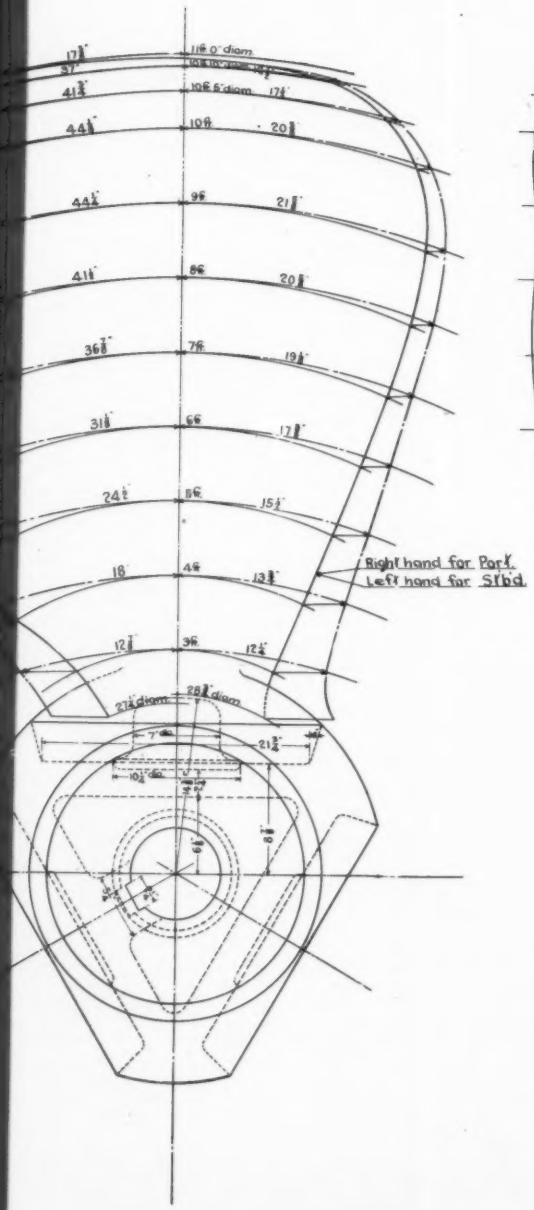
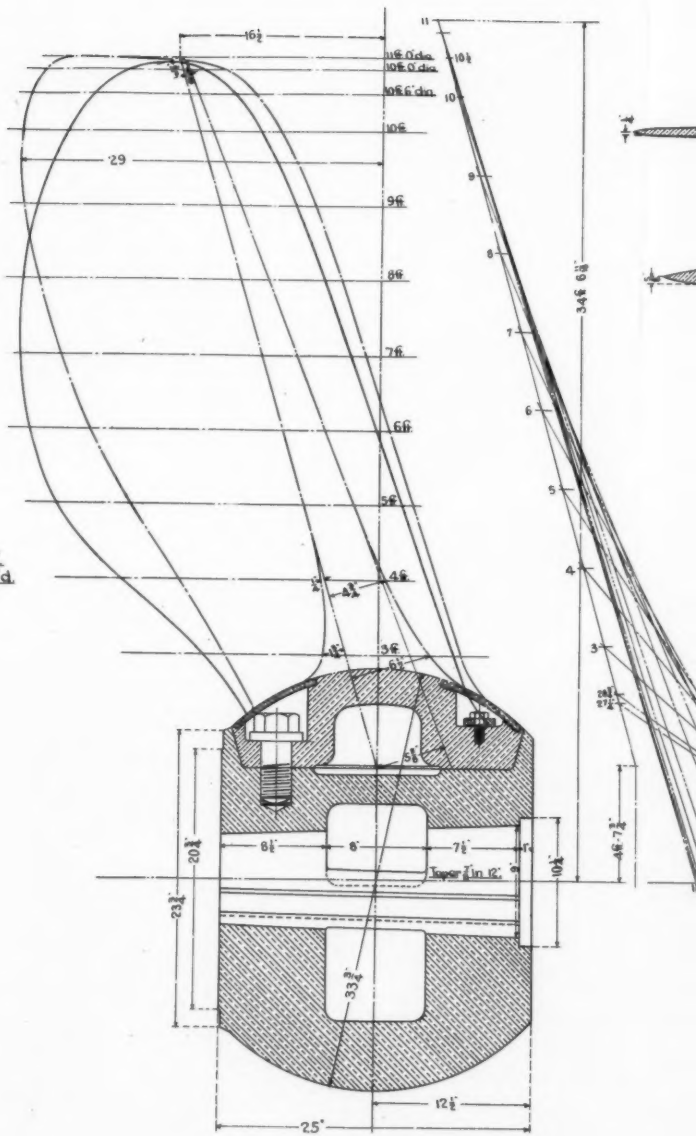


Fig. 2.

U. S. S. "DENVER."

Proposed propellers for new trials.


11ft 0" diam
10ft 6" diam
Right hand for Port.
Left hand for Stbd.
27½ diam
28½ diam


16½
29
11ft 0" dia.
10ft 6" dia.
Taper ¼in 12"
346 6½
2.5"
12½

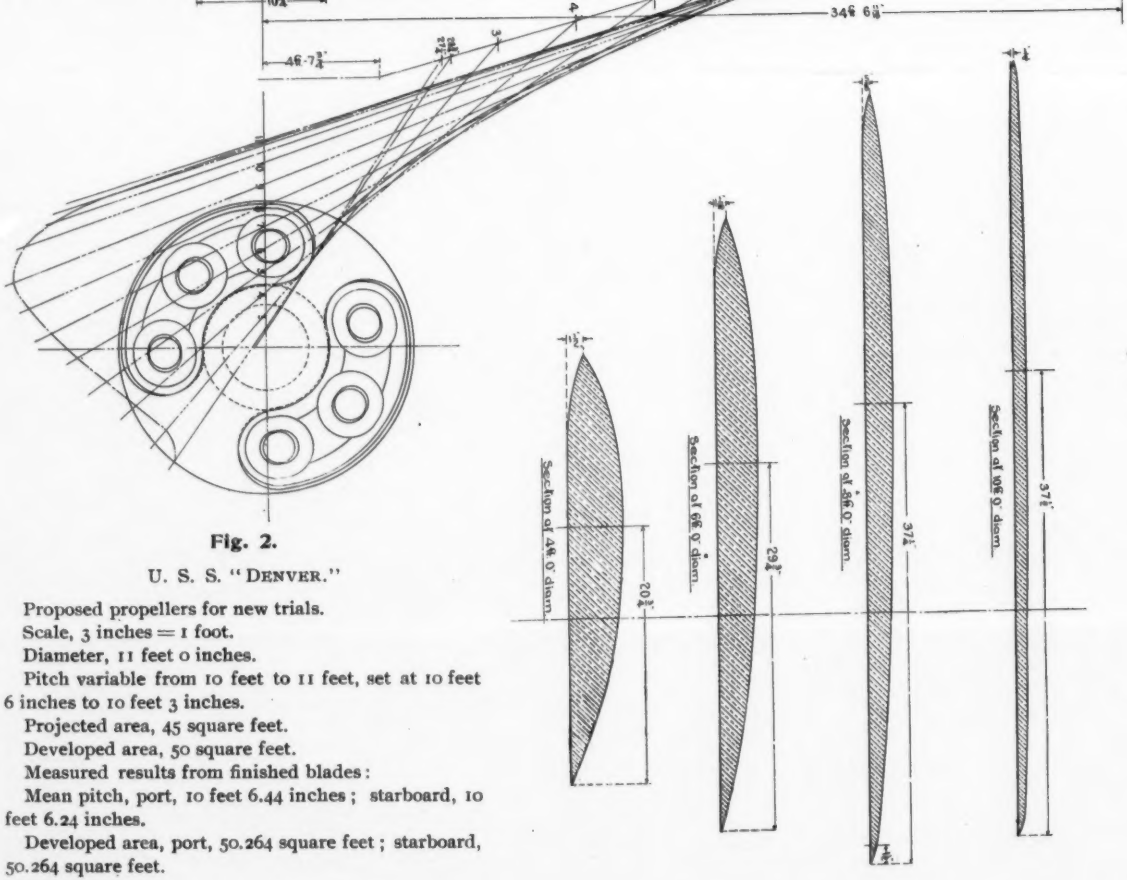


Fig. 2.

U. S. S. "DENVER."

Proposed propellers for new trials.

Scale, 3 inches = 1 foot.

Diameter, 11 feet 0 inches.

Pitch variable from 10 feet to 11 feet, set at 10 feet 6 inches to 10 feet 3 inches.

Projected area, 45 square feet.

Developed area, 50 square feet.

Measured results from finished blades:

Mean pitch, port, 10 feet 6.44 inches; starboard, 10 feet 6.24 inches.

Developed area, port, 50.264 square feet; starboard, 50.264 square feet.

Crank webs, thickness, inches	5½
Thrust shaft, diameter, inches	9½
coupling flange, diameter, inches	17
axial hole, diameter, inches	5⅜
collars, number, each shaft	11
diameter, inches	14
thickness, inches	1⅛
space between, inches	3
length, feet and inches	7– 4
Line shafts, port (one), diameter, inches	9
axial hole, diameter, inches	5⅜
length, feet	25
starboard (one), diameter, inches	9
axial hole, diameter, inches	5⅜
length, feet	25
Stern-tube shaft, diameter, inches	9
axial hole, diameter, inches	5⅜
length, feet and inches	38– 5½
Propeller shaft, diameter, inches	9
axial hole, diameter, inches	5⅜
length, feet and inches	20– 3

Screw Propellers.—The propellers have each three blades, adjustable pitch, and made of manganese-bronze, with blades bolted to hubs by Tobin bronze tap bolts, secured by lock plates.

The propellers turn inboard when going ahead. Each propeller is secured to its shaft by one feather key and a nut locked in place.

Number of blades	3
Diameter, feet	11
Length of hub, inches	25
Diameter of hub, inches	33½
Mean pitch as set, feet	11.083
Helicoidal area, each screw, square feet	41.76
Projected area, square feet	36
Disc area, square feet	88.8
Pitch ÷ diameter	1.007
Helicoidal area ÷ disc area	.470
Projected area ÷ disc area	.405

The above data is for the propellers used on the official trial, October 22, 1903. New propellers of different diameter and pitch are being designed to replace the above. Figs. 1 and 2 show respectively the propellers used October 22, and those proposed for the coming trials.

Main Condensers.—There are two main condensers, one for each engine. The shells are of wrought-steel plate, stiffened with angle bars, and with angle bars riveted around each end to form flanges for securing the water chests.

The water chests are of composition, tubes and tube sheets of Muntz metal. The water chests for the entrance and exit of circulating water have division plates fitted with valves worked by levers on the outside of condenser, to allow the circulating water to pass overboard direct, when the valves are open, when pumping from the bilge.

Defiecting plates are fitted at the exhaust nozzles; also baffle plates to direct the steam over the tubes.

Diameter of shell, inside, inches	52½
Thickness of shell, inch	¼
Tubes, diameter, inch	⅝
length between the tube sheets, feet and inches	9– 2
thickness	No. 18 B.W.G.
number in one condenser	2,004
Cooling surface, each condenser, square feet	3,005
total, square feet	6,010
Ratio, total cooling to total heating surface	1 to 2.16

Main Air Pumps.—For each engine there is one vertical, single-acting air pump, worked from the forward low-pressure crosshead. Diameter of pump piston, 22 inches, and stroke, 10 inches. The pump valves are made of three flat disks of rolled manganese-bronze, each $\frac{1}{32}$ inch thick, fitted with springs.

Main Circulating Pumps.—For each main condenser there is one double-inlet, centrifugal, circulating pump, driven by a vertical compound engine, with cranks at right angles. The H.P. cylinder has a diameter of 5 inches, the L.P. cylinder 10 inches, with a stroke of 6 inches. The pump runner is 36 inches in diameter, and width of runner at periphery, $3\frac{15}{16}$ inches. The suction and discharge nozzles are 13 and 12 inches, respectively. The suction has two branches, one leading from the sea and the other from the main drain and engine-room bilge, through a Macomb strainer. On each of these two branches there is a screw-down valve placed to open toward the pump. The injection valve and the valve on branch to the bilge are so interlocked that when one

is open the other is shut. In addition to the above, the branch from the sea is fitted with a safety sluice-gate valve. Each of these pumps is capable of discharging 5,000 gallons per minute from the bilge.

Auxiliary Condensers.—In each engine room is an auxiliary condenser with combined horizontal air and circulating pump. The shells are wrought-steel plate, heads of composition, and tube plates of Muntz metal. Diameter of air cylinder, 7 inches; circulating-water cylinder, 10 inches; steam cylinder, 6 inches, with a common stroke of 10 inches.

Diameter of shell, inside, inches	24
Thickness of shell, inch	$\frac{1}{4}$
Tubes, diameter, inch	$\frac{5}{8}$
length between tube sheets, feet	6
thickness	No. 18 B.W.G.
number in one condenser	400
cooling surface, each condenser, square feet	400
total, square feet	800

Feed-Water Heaters.—In each engine room is a feed-water heater, located on the suction side of the main feed pumps. Pipes and valves are arranged to by-pass the feed water around the heaters. The heaters are similar in construction to a condenser, and have each 210 square feet of tube-heating surface. Exhaust steam is the heating agent.

Boilers.—There are six Babcock and Wilcox water-tube boilers, designed for a working pressure of 275 pounds per square inch. Four are located in the forward fire room and two in the after fire room. Each boiler is fitted with a Foster, combined self-closing and automatic 4-inch stop-valve, closing in case of accident to the boiler or the main steam pipe. One $2\frac{1}{2}$-inch twin safety valve is fitted to each boiler. Each furnace is fitted with a spray nozzle for putting out fires by spraying water into the furnaces. Water for this purpose is furnished by the fire-room bilge pump in the forward fire room.

There are two smoke pipes. The forward one is connected to the two forward boilers in the forward fire room, and the after one to the two after boilers in the forward fire room and the two boilers in the after fire room.

BOILER DATA.

Steam pressure, designed, pounds	275
at engine, pounds	250
Number of boilers	6
Steam drums, diameter, inside, inches	42
thickness, inches	$\frac{21}{32}$
width over casing, feet and inches	9- 2
height, feet and inches	12- $\frac{31}{32}$
Furnaces, width grate, feet and inches	7- 8
length grate, feet and inches	6- 6
number of furnace doors	3
tubes, diameter, inches	2 and 4
number, 2-inch	406
4-inch	32
Heating surface, tubes, six boilers, square feet	13,200
Grate surface, six boilers, square feet	300
Ratio H. S. to G. S.	44 to 1
Smoke pipes, number	2
Smoke pipe, forward, diameter, feet and inches	4- 3
after, diameter, feet	6
Ratio smoke pipe area to G. S.	1 to 7.23
Height smoke pipe above grate, feet and inches	73- 3

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by three Sturtevant blowers, two for the forward fire room and one for the after fire room. The fans are driven by double upright enclosed engines; diameter of cylinders, 5 inches, by 4-inch stroke. The diameter of fans is 54 inches; width at rim, 15 inches.

Feed Pumps.—There are two main and two auxiliary feed pumps, of the Davidson double-acting plunger type, all of the same size, 10 inches by 7 inches by 12 inches. The main feed pumps are located one in each engine room, and the auxiliary feed pumps one in each fire room.

The main feed pumps draw from the communicating pipe between feed tanks, from the hot-well tanks and from the reserve feed-water tanks, and deliver into the main feed pipes and reserve feed-water tanks, the delivery pipe into tanks being a branch of the feed pipe, with a valve in it.

The auxiliary feed pumps are arranged to draw from the feed tanks, the sea, the main and secondary drains, and to deliver into

the boilers, the fire main, overboard and into the ash ejectors for discharging ashes overboard.

Fire and Bilge Pumps.—A fire and bilge pump of the Davidson vertical, single-cylinder type, 7 inches by 7 inches by 12 inches, is located in each engine room, connected up to draw from the sea, the engine-room bilge, the main and secondary drains and drainage manifolds, and to discharge overboard and into fire main.

Hotwell Pumps.—A hotwell pump of the same type and dimensions as the fire and bilge pump is located in each engine room, and connected to draw from the hot well, the air-pump suction pipe, the reserve-feed tanks and from the sides of the ship above the water line for taking in fresh water for boilers, and to discharge into the feed and reserve-feed tanks.

Water-Service Pumps.—A water-service pump of the same type and dimensions as the fire and bilge pump is located in each engine room and connected to draw from the sea, and to deliver into the engine-room water-service pipes, into the fire main and into the distiller circulating pipe, through which the water may be passed either overboard or into the flushing main.

Fire-Room Bilge Pumps.—A fire-room bilge pump of the same type and dimensions as the fire and bilge pump is located in each fire room, and connected to draw from the sea, the bilge and the boilers, and to deliver to the sea, the fire main and to the reserve feed-water tanks. This pump also furnishes water for extinguishing fires in the furnaces.

Feed Tanks.—There is a feed tank of 500 gallons capacity in each engine room at the height of the protective deck. Floats in the feed tanks control the throttle valves on the main feed pumps to insure a constant water level in the feed tanks and keep the feed-water heaters always full.

Hotwell Tanks.—There is a hotwell tank of 1,200 gallons capacity in each engine room. A part of each tank is fitted as a filter, through which passes the water discharged by the air pump. Floats in these tanks control the throttle valves on the hotwell pumps.

Ash Hoists.—Two ventilators in each fire room, one on each

side, are fitted for hoisting ashes. A Williamson engine, having two cylinders with cranks at right angles, is located in each fire-room hatch at the level of the gun deck. The reversing gear is operated from the gun deck. Bells with pulls are fitted for signalling when hoisting ashes.

Ash Ejectors.—One ash ejector is located in each fire room, connected to the auxiliary feed pumps in fire rooms, for discharging ashes overboard above the water level.

Reserve-Feed and Fresh-Water Tanks.—The inner bottom, from frames 41 to 50, is fitted as reserve feed-water tanks, with a capacity of about 53½ tons of fresh water.

Fresh-water tanks have a capacity of 12 tons.

Steam Traps.—The main engine and dynamo steam separators, jackets, main and auxiliary steam pipes, the radiators, galley cookers and steam-heating tables in pantries, etc., are fitted with drain pipes and valves, and with automatic traps which discharge into the filter end of the hotwell tanks. The traps have by-pass pipes and valves for convenience in overhauling.

Engineers' Workshop.—The following tools are provided: One 24-inch by 10-foot screw-cutting lathe; one 10-inch by 4-foot tool-room lathe; one 24-inch drill press with drills up to 1¼ inches; one 16-inch by 24-inch column shaper with index head, swivel table and chuck; one emery grinder with two 12-inch by 2-inch wheels, one wheel fitted with surface table; one 30-inch by 4-inch grindstone. These tools are driven by a 7-inch by 7-inch vertical engine with fly wheel, driving pulley and automatic governor.

Distilling Apparatus.—The distilling plant consists of two evaporators and two distillers, with their accessories, located in the engine rooms. The evaporators are arranged so that they may be operated in double effect, and have a combined capacity of 8,000 gallons of water in 24 hours. The distillers have a combined capacity of 5,000 gallons of potable water in 24 hours, at a temperature of 90 degrees F. The evaporator feed pumps are 4½-inch by 4-inch by 6-inch vertical Davidson pumps, one located in each engine room. The circulating water for the distillers is supplied by the engine-room water-service pumps, connections

being made so that each pump may be run on the distiller in the same engine room or on both.

There is a 4½-inch by 2⅞-inch by 2⅞-inch by 5-inch combined fresh-water and brine pump in each engine room.

Ice Machine.—There is one Allen dense-air ice machine capable of producing the cooling effect of one ton of ice in 24 hours, and, connected to the ice-making tank, the cold-storage rooms and the scuttle butt.

Electric Plant.—The installation consists in general of four 24-kilowatt generating sets, all of 80 volts pressure at the terminals; 350 incandescent lamps; four enclosed arc lamps of 3 amperes capacity in engine hatch; two 30-inch searchlights; two truck lights; one electric night-signalling set; two diving lanterns, with 150-candlepower incandescent lamps; four portable electric ventilating sets; and sixteen ½-horsepower desk fans; with the necessary switchboards, wire, wiring accessories, molding, conduit tubes, fixtures, lamps, instruments, tools and spare parts usually furnished for the proper manipulation, test and repair of the plant.

The dynamos are of the direct-current, compound-wound, multipolar type, directly connected to the engines, the dynamos and engines being secured to a common bed plate. The engines are vertical, cross-compound, inverted-cylinder type, with diameters of cylinders 6½-inches and 10½-inches, by 7 inches stroke.

The ship is wired on the two-wire system.

Steam Windlass.—Forward on the gun deck there is a steam windlass built by the Hyde Windlass Company. The engine is reversible, double-cylinder, vertical, direct-acting, with cylinders 9 inches in diameter and 9 inches stroke.

Winches.—There are two electric winches built, by the General Electric Company, one located forward and one aft on the main deck.

Steering Gear.—A Williamson double-cylinder steam steering engine is located on the platform deck aft of bulkhead No. 87. Diameter of cylinders, 8 inches; stroke, 7 inches.

There are six ways in which this vessel may be steered:

first, by steam, from the forward steering station on bridge; second, by steam, from the midship steering station; third, by hand, from the midship steering station; fourth, by hand, in steering-engine room; fifth, by steam, in steering-engine room; sixth, by spare-tiller gear.

Telegraphs and Revolution Indicators.—There is a mechanical repeating telegraph for each engine, connected to transmitters on the bridge. There is also a gong for each engine, with bell pulls on bridge.

A mechanical signal system is fitted between the engine and fire rooms. Mechanical revolution indicators are fitted in each engine room, worked from the engines by positive motion, and so arranged that the relative speed of both engines can be seen on the same dial at a glance. Mechanical tell-tales are fitted on the bridge, showing the direction and revolutions of main engines.

Electric telegraphs, with dials in each engine room and connected to transmitters on bridge, are fitted, whereby the number of revolutions of the engines are transmitted.

Direct-reading electric-shaft indicators, for indicating the direction and number of revolutions of the main engines are fitted. The transmitters are located in the shaft alley and the indicating dials on the bridge.

Steering Telegraphs.—Electrical telegraphs, indicating the helm angle, are fitted, with repeating dials at all steering wheels and at steering engine, and connected to transmitters on the forward bridge, at after steering station on main deck and in the steering-engine room.

Telephones, Voice Pipes, Call Bells, Push Buttons and Annunciators.—For communication between the various parts of the ship there is a system of telephones, voice pipes, call bells, push buttons and annunciators.

OFFICIAL TRIAL.

The *Denver* left the contractors' yard October 15, 1903, for the trial course off Cape Ann. On the 16th a series of progressive runs were made by the contractors over the measured course at the Delaware Breakwater, but the results proved unsatisfactory,

owing to a misunderstanding of points marking the ranges. On the same date the *Denver* proceeded up the coast, arriving in Boston Harbor on Sunday, the 18th.

October 20th, while in Boston Harbor, a capacity test of the evaporating plant was made, under the supervision of Commander William H. Nauman, U. S. N., inspector of machinery for the vessel. The results showed the capacity of the plant to exceed the requirements of the machinery specifications.

At about 8·30 on the morning of October 22, 1903, the *Denver* left Boston Harbor for the Cape Ann course, the members of the Trial Board having come on board about 7·30 A. M. During the run out to the course the Board made its inspection of the vessel and her machinery. Before reaching the trial course the port high pressure piston rod heated, necessitating the stopping of the port engine for a few minutes to take out one turn of the soft packing, after which this rod gave no further trouble. At 10·46·47½ A. M., the *Denver* passed No. 1 stake boat on the run North.

On this run a nut on the bottom head of the starboard main feed pump slacked, and the pump was stopped long enough to set up on the joint, after which the pump was again started.

The vessel reached stake boat No. 6, the end of the first leg of 33 nautical miles, at 12·46·02.

In making the turn to get back on the course for the run South the low-pressure piston of the starboard main circulating-pump engine broke. The starboard main engine was stopped and the broken piston and the low-pressure connecting rod were removed from the circulating engine, and it was run with the high-pressure cylinder only during the rest of the trial. The vacuum was about 4 inches lower than before the accident.

At 2·06·23½, an hour and twenty minutes later, the *Denver* crossed the line on her return run. At 4·10·33 P. M. the second leg of 33 nautical miles was completed.

The corrected average speed for the four hours trial was 16.4433 knots per hour.

At the commencement of the North run, there was a gentle breeze from S. by W. with a smooth sea. The wind hauled afterwards to S.S.W., and blew very fresh on the run to the

southward with a moderate sea. The vessel pitched moderately and took considerable spray over her forecastle and bridge.

At 190 to 200 revolutions per minute, the main engines vibrated considerably, due, in part, no doubt, to the unequal distribution of power, the intermediate-pressure cylinders of both engines doing more than their share of the total work. During the trial, cooling water was run through the water jackets of the main bearings and crosshead guides. Water was allowed to trickle on the eccentric and thrust bearings merely as a precautionary measure. There was no heating of any of the journals. The valves admitting live steam to the receivers were kept cracked, and were opened wide five minutes before the end of the second run.

Indicator cards were taken from all the main-engine cylinders at an interval of 30 minutes during the four-hour trial. Considerable trouble was experienced with the indicators used on the high and intermediate-pressure cylinders. Several times the indicator pistons stuck, and upon examination the source of trouble proved to be a black, gritty and greasy substance resembling iron filings. The post-trial examination no doubt solved the question, when it was found that the high and intermediate-piston packing rings were badly worn. It was the metal worn from these rings that had gotten into the indicators.

The feed system on this vessel worked well. The main feed pumps are located in the engine rooms, and always under the control of the engine-room force. The throttle valves of the main feed pumps are controlled by floats in the main feed tanks. Likewise, the hotwell pumps are controlled by floats in the hotwell tanks. This arrangement has never failed to give a constant automatic feed supply, and needed no attention from the engineering staff. Five tons of fresh water was used during the time the vessel was on the trial course.

The boilers performed well, supplying readily the necessary steam. On both runs the safety valves blew off several times. While in Boston Harbor, prior to the trial, the springs in the reducing valves in main steam pipes at the engines were removed, by permission of the Navy Department, with the directions that

the steam pressure at engines should not at any time exceed 250 pounds.

The coal used on the trial was Pocahontas, hand-picked, and had been previously bagged. The amount of coal consumed was estimated from the number of empty bags collected during the trial.

At the end of the four hour trial the steering gear was tested with the following results: Time required to put helm from amidships to hard-a-starboard was 12.2 seconds; time taken by one man to put the helm from hard-a-starboard to hard-a-port varied between 25 and 22 seconds, and with two men working hand-wheel, the time required to put the helm from hard-over to hard-over was reduced to 18 seconds. This test was considered to be satisfactory, except that the lead from the forward bridge to the steering engine should be overhauled in order to make the helm work more readily.

On account of the late hour and the fact that it was becoming dark, it was not considered practicable to make a test of the anchor engine, the Board having been informed by the contractors that they would apply for another speed trial.

The draught was taken at 6·40 A. M. The vessel, at this time, was in the inner harbor at Boston, and the conditions for taking the draught were favorable. The draught was, forward, 14 feet 11 inches; aft, 16 feet 8½ inches; mean, 15 feet 9¾ inches,

At this time the Trial Board and about fifty guests had not yet arrived on board. A small steam launch was down, that was subsequently hoisted on board and carried during the trial, and the vessel was anchored. Correcting for these items, the displacement of the vessel at 8·30 A. M., when starting from Boston for the trial course, was 3,227.5 tons, being composed as follows:

Displacement by draught figures, tons, .	3,219
Weight of launch, tons, ...	2.5
Weight of anchor and chain, tons, . .	2.8
Weight of Trial Board and guests, tons, .	3.2
Displacement when starting for trial, tons,	3,227.5

The allowance of 27.5 tons was considered satisfactory to carry the vessel from Boston to the middle of her trial, so as to provide that the mean displacement during her trial should be no less than 3,200 tons.

PERFORMANCE.

Steam pressure at boilers (per gauge), pounds	254
H.P. steam chest, S.engine (per gauge), pounds.	Not given.
P. engine(per gauge), pounds.	233.25
1st receiver, S. engine, absolute, pounds	128.8
P. engine, absolute, pounds	128.6
2d receiver, S. engine, absolute, pounds	33.49
P. engine, absolute, pounds	33.2
Vacuum in condensers, in inches of mercury, port	24.3
starboard	22.5
Mean effective pressures in cylinders, in pounds per square inch :	
Main engines, starboard, H.P.	90.94
I.P.	58.18
forward L.P.	16.2
after L.P.	15.18
port, H.P.	94
I.P.	57.87
forward L.P.	15.93
after L.P.	16
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	46.558
port	47.13

AUXILIARY MACHINERY.

Pump, air, main	Attached.
auxiliary	Not used.
circulating, H.P. cylinder	72.6
L.P. cylinder	22.5
Dynamo engines, H.P. cylinder	26.25
L.P. cylinder	6.875

REVOLUTIONS PER MINUTE.

Main engines, starboard	198.12
port	200.25
Pumps, air, main	Attached.
circulating, starboard	220
port, counter	212.5
main feed, double strokes per minute, starboard	31.6
port	30.9
auxiliary, water-service, double strokes per minute	12.25

Pumps, auxiliary, fire and bilge, double strokes per minute	40
hotwell, double strokes per minute	7
Blower engines (forced draft), revolutions	287.2
Speed of ship in knots per hour, corrected	16.4433
Slip of propeller in per cent. of its own speed, based on mean pitch:	
Starboard	24.14
Port	24.95
Air pressure in fire rooms, in inches of water	.957
ash pit, in inches of water	.908

INDICATED HORSEPOWER.

	Starboard.	Port.
Main engines, H.P.	675.37	705.59
I.P.	1,146.80	1,153
F. L.P.	478.10	475
A. L.P.	447.80	477
total	2,748.07	2,810.59
Air pumps, main		Attached.
Circulating pump, main, starboard		20.875
port		20.875
total		41.75
Hotwell pumps, total		5.80
Water-service pumps, total		8.2304
Fire and bilge pumps, total		2.60
Main feed pumps, total		32.75
Blower engines for forced draft in fire rooms, total		16.66
Ventilating for ship and engine rooms		Electric.
Dynamo engines, one in use during trial		20.45
Collective of all main engines		5,558.66
main engines, air, circulating, and feed pumps		5,633.16
main and auxiliary engines in operation during trial		5,686.9
all machinery during trial, per square foot of G.S.		18.956
H.S.		.4308
Main engines, air, circulating, and feed pumps, per sq. ft. of G.S.		18.7772
H.S.		.4267

COAL.

Kind and quality	Pocahontas, hand-picked, excellent.
Pounds per hour	12,250
per I.H.P. collective, all machinery in operation	2.1541
per I.H.P. collective, main engines, air, circulating and feed pumps	2.175
per square foot of G.S.	40.83
H.S.	.928
Cooling surface, square feet per I.H.P.	1.06
Heating surface, square feet per I.H.P.	2.33

OFFICIAL TRIAL, U. S. S.

No. of run.	Time.	Time interval.	Reading of counter.	Revolutions during interval.	Revolutions per minute.	Steam pressures. In boilers above atmosphere.	Steam pressures. In st'm pipe at engine above atmosphere.	Steam pressures. In H.P. steam chest, absolute.	Steam pressures. In I.P. receiver, absolute.	Steam pressures. In L.P. receiver, absolute.	Vacuum.
	h. m. s.	*m.*									**PORT**
North run.	10·46·47½	...	397,819	...	...	...	230	240	127	32.5	23
	11·01·47½	15	400,808	199.3	200	244.5	232	243	128	33.5	24.5
	11·16·47½	15	403,845	202.5	...	248	232	238	127	33	24.5
	11·31·47½	15	406,849	200.3	206	247.5	235	242	129	33.5	24.5
	11·46·47½	15	409,899	203.3	...	252.5	239	249	130	34.5	24.5
	12·01·47½	15	412,951	203.5	204	...	240	251	130	34.5	24.6
	12·16·47½	15	416,000	203.3	...	257	242	253	130	34.5	24.6
	12·31·47½	15	419,062	204.1	204	254	245	255	131	34.8	24.6
	12·46·02	...	421,970	...	...	...	245	255	131	34	24.6
South run.	2·06·23½	...	435,642	...	...	...	230	240	121	32	24
	2·21·23½	15	438,577	195.7	197	246	245	255	125	32.5	23.7
	2·36·23½	15	441,590	200.9	...	262	247	258	132	32.5	23.7
	2·51·23½	15	444,582	195.5	198	260	247	259	134	35	24.3
	3·06·23½	15	447,587	200.3	...	...	247	258	135	35	24.3
	3·21·23½	15	450,547	197.3	200	259	246	254	132	34.5	24.4
	3·36·23½	15	453,502	197	...	...	243	250	130	34	24.5
	3·51·23½	15	456,460	197.2	198	253	239	245	128	33	24
	4·06·23½	15	459,422	197.5	...	...	237	240	127	33	24
	4·10·33	...	...	191.9	...	...	230	240	120	30	24
											STARBOARD
North run.	10·46·47½	...	396,490	...	...	..	226	235	120	31	25
	11·01·47½	15	399,645	210.3	206	244.5	236	245	125	33	24.5
	11·16·47½	15	402,648	200.2	...	248	235	244	125	33	24.5
	11·31·47½	15	405,640	199.5	198	247.5	220	230	123	33	24.25
	11·46·47½	15	408,668	201.9	...	252.5	230	240	127	34	24.25
	12·01·47½	15	411,693	201.7	201	...	246	256	127	34	24.25
	12·16·47½	15	414,728	202.3	...	257	240	248	130	34	24.5
	12·31·47½	15	417,760	202.1	203	254	230	240	130	34.5	24.5
	12·46·02	...	420,430	...	...	...	240	248	133	35	24.25
	‡										
South run.	2·06·23½	...	429,910	...	...	...	238	247	120	31	20.75
	2·21·23½	15	432,860	196.7	197	246	230	239	123	33	20.75
	2·36·23½	15	435,830	198	...	262	240	248	135	35	20.25
	2·51·23½	15	438,790	197.3	199	260	240	248	136	35	20.25
	3·06·23½	15	441,745	197	...	...	245	253	137	35	21
	3·21·23½	15	444,650	193.7	194	259	238	246	134	34.5	21.25
	3·36·23½	15	447,558	193.9	...	...	240	248	133	34	21
	3·51·23½	15	450,460	193.5	194	253	242	250	132	34.25	21
	4·06·23½	15	453,370	194	...	...	240	248	130	34.5	20.75
	4·10·33	...	454,180	194.8	...	...	241	249	130	34	20.5

• Aft. † Forward. ‡ Starboard engine. Interval between north and south runs due to delay by breakdown of starboard circulating pump engine.

DENVER, OCTOBER 22, 1903.

Link.	Temperatures.											Revs. or double strokes per min.					Air pressure in inches of water.	
	Atmosphere.	Engine room.		Fire room.		Injection.	Discharge.	Hotwell.	Feed.	Base of smoke pipe.		Air pump.	Circulating pump.	Water-service pump.	Feed pump.	Fire room blowers.		
		Upper platform.	Working platf'm.	Above grating.	Working level.													
ENGINE																		
Full gear.	50	116	95	...	...	54	72	120	...	...					22	...	.6	.6
	50	116	95	115	90	54	72	120	160	750*					22	265	.6	.6
	50	118	95	...	...	54	74	120	174	...					26	...	.7	.8
	50	118	95	...	...	54	74	122	...	760*					30	233	...	...
	50	120	97	118	92	54	76	124	...	...					30	...	.8	.9
	50	120	98	...	...	54	76	124	...	740*					32	...	.9	...
	50	120	98	...	...	54	76	125	170	...					32	268	.9	1
	50	122	98	...	...	54	78	122	...	760*					36	...	...	1
	50	122	100	...	...	54	78	122	170	...					36	...	...	...
Full gear.	50	123	100	...	...	54	76	133	...	580†					38	...	...	1.1
	50	123	100	...	...	54	76	136	...	...					38	345	1	1
	50	125	102	...	...	54	76	138	182	630†					36	...	1	1.2
	50	126	103	110	110	54	76	130	...	..					36	...	.8	1.1
	50	128	103	...	...	54	77	134	...	630†					32	...	1	.75
	50	128	103	...	...	54	77	134	...	...					28	258	.9	...
	50	130	104	...	...	54	78	132	186	620†					28	...	.8	1
	50	130	104	...	...	54	79	130	...	...					30	...	.8	1
	50	132	105	...	...	54	79	130	186	620†					28	...	1.1	1.1
	50	132	105	...	...	54	79	130	...	620†					28	...	1.1	...
ENGINE																		
Full gear.	...	118	96	...	...	54	62	118	...	...					...	...	.6	.6
	...	120	98	115	90	54	62	122	160	750*					42	265	.6	.6
	...	121	99	...	...	54	62	120	174	...					44	...	.7	.8
	...	121	100	...	...	54	62	119	...	760*					36	233	...	...
	...	122	101	118	92	54	62	119	...	...					37	...	.8	.9
	...	122	102	...	...	54	62	118	...	740*					38	...	.9	...
	...	124	101	...	...	54	62	117	170	...					28	268	.9	1
	...	125	100	...	...	54	62	118	...	760*					28	...	...	1
	...	126	102	...	...	54	62	116	170	...					29	...	...	...
Full gear.	...	126	101	...	...	54	63	136	...	580†					32	...	...	1.1
	...	126	102	...	...	54	63	134	...	...					32	...	1	1
	...	124	104	...	...	54	64	136	182	630†					28	345	1	1.2
	...	124	106	110	110	54	64	136	...	...					29	...	.8	1.1
	...	126	108	...	...	54	64	136	...	630†					28	...	1	.75
	...	128	110	...	...	54	64	135	...	...					29	...	.9	...
	...	130	106	...	...	54	64	136	186	620†					28	325	.8	1
	...	130	108	...	...	54	64	135	...	...					28	...	.8	1
	...	132	108	...	...	54	64	134	186	620†					26	...	1.1	1.1
	...	132	110	...	...	54	64	135	...	...					28	...	1.1	...

Attached. — Av. 216. — Av. 230. — Av. 212.5 (counter). — Av. 212.5 (counter). — Av. 12. — Av. 12. — Attached. — Attached.

Av. 12.5. — Av. 12.5.

Coal used on trial, 49,000 pounds. Coal per hour, 12,250 pounds.
Kind of coal, Pocahontas.

POST-TRIAL EXAMINATION.

The post-trial examination of the machinery, boilers and appurtenances of the *Denver* was made by the Machinery Trial Board November 9th, at the works of the contractors. Generally speaking, everything was found in good condition.

The bore of the starboard high-pressure cylinder liner was found to be in such a condition that the piston at top stroke did not override the counterbore, while on the bottom there was too much of an override.

The high and intermediate piston rings of both engines were found to be considerably worn, the greatest wear on all the rings being opposite the slit in the rings. The Babbitt metal of the forward horseshoe of the starboard thrust bearing was found to have heated to the extent that the metal had run and partly filled up the oil grooves.

About the line of water level in the steam drums of the boilers there was a slight coating of grease. Some of the grate bars immediately in line with the opening of the furnace doors were found to be slightly burnt, but still in serviceable condition.

BUILDERS' TRIAL AT THE DELAWARE BREAKWATER, NOVEMBER 24, 1903.

Subsequent to the Boston trial the contractors submitted a design for new propellers having a diameter of 12 feet, but this was not approved by the Navy Department, on account of the extension of the propeller tips below the line of keel. The contractors then decided to reset the old blades to a pitch of about 9 feet 9 inches instead of 11.083 feet, used on first trial.

The *Denver* was docked and the blades were adjusted on the hubs, but upon careful measurement it was found that the starboard propeller was set only to about 9 feet 6 inches, while the port was 9 feet 9 inches. The time limit for the dock was up, so there was no time to correct the setting of the starboard propeller.

The valve gear of the intermediate-pressure cylinders was adjusted to give a later cut-off, in order more equally to divide the power among the cylinders.

With these changes and a general overhauling of the machinery,

PROGRESSIVE TRIAL U. S. S. *DENVER*, NOVEMBER 24, 1903.

Running number.	Elapsed time, m = min. s = sec.		Total revolutions during run.		Revolutions per minute.		Steam pressures, pounds. At engines.		H.P. Chest.		I.P. Chest.		L.P. Chest.		Vacuum.		Throttle.		Jackets. H.P.		I.P.		F.L.P.		A.L.P.		Current = c.	Length of course = D.	ct.	$D - ct = ts$.	Speed = S.	Slips, per cent. Port.	Starboard.	Average.	Temperatures, degrees Fahrenheit. Smoke pipes.	Engine room. Injection.		Discharge.		Hotwell.		Feed.		Running number.
	m.	s.	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S									Aft	Fd	P	S	P	S	P	S	P	S	
1	12	39	832	839	65.7	66.3	165	160	32	19.5	6	2	—10	—11	27	24	C.	C.	165	42	45	62	35	27	38	26	...	...	...	...	...	...	...	...	470	...	46	46	50	54	74	..	143	...	1
2	17	38.5	1137	1171	66.88	66.4	206	203.5	13	20.5	..	3	—14	—12	27	23.5	C.	C.	200	49	50	70	38	27	40	27.5	—1	1.261	.294	1.555	5.29	17.7	15	16	35	...	520	46	46	50	54	74	92	136	148	2
3	8	28	870	883	102.9	100 4	173	168	40	41.5	8	9	—11	—10	28.5	25.75	.03	C.	170	50	40	55	25	6	27	4	+.9	1.261	.127	1.134	8.04	17	14	6	15.8	500	...	46	46	53	54	74	94	...	150	3
4	9	59.5	1005	1022	100.5	102 4	167	172.5	26	25	4	2	—12	—12	27.6	25.5	.03	C.	165	43	40	56	23	4	25	4	—.6	1.261	.1	1.361	8.166	17	14.9	15.95	...	...	46	46	53	54	74	92	...	144	4
5	6	25.5	901	943	140.4	144.5	172	168.5	70	77.5	20	20	—6	—5	28.6	26.125	.07	C.	170	60	38	50	7	...	10	...	+ 4	1.261	.043	1.218	11.38	16	5	16	16.25	590	...	46	46	56	55	74	92	...	136	5
6	6	31.5	948	936	145.1	143.2	190	202.5	75	55	22	20	—5	—6	28.8	26.125	.07	C.	185	60	38	54	4	...	5	...	...	1.261	...	1.261	11.57	16	5	13.8	15	15	...	560	46	46	56	55	74	90	...	128	6
7	5	54	952	1006	161.4	170.5	190	190	88	128.5	28	26	—2	1	28.8	26.25	.1	.13	190	85	38	53	3	...	5	1	—.27	1.261	.0266	1.288	13.10	16.4	18	17.2	...	...	46	46	60	55	76	82	...	126	7
8	5	34	915	930	164 4	166.9	...	221	...	90	..	21	...	—2	...	26.5	.1	.13	190	75	43	58	5	1.5	6	1.5	+.5	1.261	.0464	1.215	13.10	16	4	16.3	16	35	620	...	46	46	..	55	..	..	...	...	8
9	5	31	1034	1022	187.3	185 1	195	195	141	134	51	40	5	4	29	26.5	.3	.2	195	100	43	56	5	1	6	2	— 7	1.261	.0644	1.325	14.40	19	17	18	...	...	46	46	66	55	76	74	...	122	9
10	4	56.5	902	929	182.6	188.1	160	170	110	122.5	58	35	2	3	29	26.25	.3	.25	160	100	40	51	5	1	7	1	+.9	1.261	.0741	1.187	14.42	19	18.2	18	6	670	...	46	46	56	55	76	74	...	115	10
11	5	21	1048	1090	195 9	203.8	210	210	146	167	57	60	7	9.25	28.8	26 5	.55	.3	210	120	45	62	9	2	10	4	—1.1	1.261	.098	1.359	15.24	19	20.2	19.6	730	...	46	46	70	65	78	74	...	115	11
12	4	43	*	954	*	202.5	205	210	150	167	5	55	63	6	9	75	29	26.625	.55	.3	205	125	45	62	9	4	10	4	+1.3	1.261	.102	1.159	15.28	19	19.5	19.25	...	...	46	46	70	65	78	74	...	115	12
13	5	08	1108	1124	214.4	217.5	210	205	198	195	75	74	14.5	15.5	28 5	26.25	.7	.5	210	150	45	66	9	7.5	10	8	—1.75	1.261	.151	1.412	16.52	19.9	18.9	19 4	850	...	46	46	74	78	82	76	...	115	13
14	4	06.5	898	928	218.6	225.9	215	217.5	207	215	76	78	16	17	28 5	26.125	.7	.55	215	150	45	66	9	9	10	9	+1 84	1.261	126	1.135	16 58	21.5	21.7	21.6	...	...	46	46	74	..	82	80	...	122	14
15	5	09	1132	1149	219.9	223.1	213	210	210	205	87	77	17	16 75	28.5	26	.7	6	210	150	45	64	10	9	12	9	—1.84	1.261	.158	1.419	16.54	21.5	20 9	21.2	...	...	46	46	74	..	..	80	...	134	15

Position of Links: Full gear for both engines.
* Engine stopped because of broken indicator gear.
C = cracked.

The current column was obtained from a current curve, points on which were obtained by using the elapsed time while running with and against the current, engines running as nearly as practicable at same number of revolutions. This was done by the formulae

$$D + ct_2 = St_2$$
$$D - ct_1 = St_1$$

where c = current in knots.
D = length of course in knots.
t_2 = elapsed time while running against current.
t_1 = elapsed time while running with current.
S = speed in knots.

Eliminating S we get the expression for c as follows:

$$C = D\frac{t_2 - t_1}{2t_1t_2}.$$

After getting points by this formula a fair curve was drawn, and ordinates at the middle times of each run were measured.

After the current was obtained for each run the current was applied in the formula

$$D - ct = St,$$

current (c) being considered positive when running in same direction as the ship. This gave the speed (S) for each run.

the *Denver* was given a progressive trial November 24, 1903, at the Delaware Breakwater.

Arrangements were made to run both ways over the trial course at speeds of 6, 9, 12, 14, 15, 16 and 17 knots. It was estimated by the contractors that 67, 100, 136, 160, 175, 190 and 205 revolutions, respectively, would give these speeds. An additional single run was made over the course, running at full speed.

During runs 11, 12, 13, 14 and 15 forced draft was used; ½ inch pressure at the blower was recorded during runs 11 and 12, and this increased during runs 13, 14 and 15 until 1½ inches was reached. During run 12 the indicator gear on the port intermediate-pressure cylinder broke, and the port engine was stopped before the completion of this run.

George's Creek coal, ordinary run of the mine, was used during the trial. With the air pressure at 1½ inches at the blowers the pyrometer in the after smoke pipe recorded 850 degrees. With ½ inch air pressure the pyrometer recorded 695 degrees.

The starboard F. L.P. crank pin heated slightly, but was cooled with water and gave no further trouble. There was little vibration of the engines, due, no doubt, to the more even distribution of power in the cylinders.

Upon the failure of the vessel to attain a speed of 17 knots on the trial of November 24th, the builders decided to substitute new propellers with a greater helicoidal area and a pitch of about 10 feet 6 inches.

The starboard high-pressure cylinder liner has been replaced by a new one, and all high-pressure and intermediate-pressure steam piston rings have been replaced by new ones of a different design and of a harder metal.

Work on the new propellers is being pushed, and the *Denver* ought to be ready for trial about February 15th.

NOTES.

There seems to be plenty of room everywhere on board the *Denver* except in the engine department. Owing to the crowded condition of the machinery in the engine rooms, it will be impossible to do rapid overhauling and examination of parts. The

after ends of the engine rooms are particularly crowded. This is due largely to the encroachment upon machinery space by ammunition magazines located between the line shafting. If these magazines could be located in some other part of the ship, a much better arrangement of auxiliaries and piping could be had. At present, it will be very difficult to retube the auxiliary condensers.

The present location of the evaporators could not be much worse for difficult handling and slow overhauling. They are located on raised platforms, close under the deck, in the after-part of the engine rooms, almost immediately over the thrust-bearings. To remove the coils for scaling or renewing, it was found necessary to remove the waste tanks from their original positions.

On January 13th, a time test was made to find out how long it would take to remove the coils for scaling. The condition of starting was with everything intact as in service condition, ladder, gratings, pipes, etc., all in place. The time elapsing from start until the time the evaporator coil was in position for scaling was one hour and forty-five minutes. During this time the handling of the coil, though very inconvenient, gave no serious trouble, except when the front flange was passing the corner of the oil tank. At this time the back flanges were just passing through the opening in the front of the shell. After this point was passed, the coil came out with reasonable ease. The actual work of removing the coil was done by one leading machinist, one rigger and two helpers. Two engineers were also present, and occasionally made suggestions concerning the work.

When removed, the coil and shell were very clean, and no interference or trouble was experienced from scale; moreover, the ship was absolutely without motion, so that the time required may be considered as a minimum at 1¾ hours for preparation for scaling.

Before the coil was put back into the shell, skids were fitted to assist in handling the coil; the upper corners of the back steam chest were trimmed off, the rivets in the guide strips smoothed off, and gaskets were cut for joints. The coils were put in after

these preparations, on January 18th. The time necessary to put the coils in place and get everything back to service conditions, with evaporator ready for starting, was two hours and thirty minutes; the work done on the back steam chest and on guide-plate rivets having materially assisted in the entrance of the coils.

A number of suggestions have been made to relieve the cramped condition of the distilling plant, by carrying out of any one of which the efficiency of the plant would be increased very greatly.

It has been suggested that the evaporators and distillers be taken out of the engine rooms and located on the berth deck between frames 29 and 33, between the machinery workshop and the ice-machine room. In this arrangement the man on watch at the ice machine could also give the necessary attention to the evaporators.

Another suggestion was to place the evaporators on the upper deck between the smoke pipes. If the evaporators were taken out of the engine rooms the auxiliary condensers could be placed in a fore-and-aft position, which would permit them to be retubed easily, and would also relieve the crowded condition in this part of the engine-room space.

Still another suggestion was to install, in place of the two auxiliary condensers in the engine rooms, one auxiliary condenser of a somewhat larger capacity in one engine room, and in the other engine room to install one evaporator for make-up feed purposes. Then to install a second evaporator, for ship's use, forward on the berth deck. By this last arrangement a part of the distilling plant would be below the protective deck.

THE ROTATION OF PROPELLERS.

By Chief Engineer Fred. G. McKean, U. S. N., Member.

From a careful perusal of M. Laubeuf's article in the Journal of November, 1903, on the rotation of propellers on twin-screw vessels, we venture to think that that gentleman, eloquent and skillful though he is in marshalling certain facts, does not necessarily prove the whole of his point, nor carry complete conviction to the thoughtful reader. He maintains that the better arrangement in all cases is that in which the starboard screw, viewed from the stern, revolves in the direction of the hands of a watch, the port screw revolving in the opposite direction.

M. Laubeuf may be correct, but we hardly think he has said the final word in the matter of propulsion efficiency; though his remarks on the advantages in maneuvering are of great weight in a man-of-war, and perhaps would settle the question in the view of most officers of the deck.

But under the head of efficiency and among the results of experience, we read on page 1182, that, in the trials of vessels fitted with screws converging above, the arrangement opposed by M. Laubeuf, there is formed a ridge or wall of water exceeding 6.5 feet in height in two vessels named. At the first glance this certainly appears to be an utter waste of power, since we do not build marine engines to pile up a wall of water at the stern. And yet, every arrangement of propellers must "hurl liquid masses" in some direction, and even in that arrangement advocated by M. Laubeuf he states that the current from the propellers appears to disperse, which is not strictly what we build marine engines for. But in obtaining the resistance for driving the ship ahead, should either of these induced currents be properly considered a waste? And even if it can, do we not recover part of the loss from the "ridge or wall" in arrangement No. 2,

while we recover nothing from the dispersed currents in arrangement No. 1? It would seem that propellers working in a greater depth should yield a greater efficiency, due to the more solid water caused by the superincumbent weight, which may approach two or three pounds if a ridge as high as 6.5 feet were directly over the propellers, lessened, of course, as the ridge is left further astern. In other words, if it be important to place a screw as deep in the water as the hull will permit, may there not be partial recovery from a ridge of water above the normal level, even though some power is exerted in forming that ridge by giving motion to the currents, and not forgetting that motion is given in some direction in any case?

Passing to the deductions from the table on page 1183, M. Laubeuf admits that in displacement and immersed midship section the vessels he favors have some advantage, but he seems to think the trial is fair enough in spite of that, because the hulls were intended to be absolutely identical, and he attributes the difference in speed of 1.5 knots to the different arrangement in the rotation of the propellers. Now the Editor of the JOURNAL, in a foot note to M. Laubeuf's article, has noted certain instances in which the "similar machinery of similar vessels" has shown greater difference in speed than in the cases mentioned by M. Laubeuf, and other instances might be given to show that, as the Irish sailor said, "sister ships always differ." Various men might explain the different performances in various ways, *e. g.*, by the workmanship, the aligning, the personal factor in setting out piston rings, the judgment in setting up on stuffing boxes, etc. Speculations such as these would be uncalled for in the course of time, and in several vessels and with changing personnel, as such differences ought to be eventually eliminated or balanced; but some of them would be suspected of exerting influence in particular trials and comparisons.

That M. Laubeuf is perfectly honest, however, is amply proved in his suggestion on page 1184, that one of the vessels in question should be tried in a series of runs in her present condition, then to go into dock, have her propellers shifted from starboard to port, and *vice versa*, and finally to make another series of runs,

the engines backing. But here, also, a critic might find a host of minor things which might vitiate the result; whether changes were made or not made in internal arrangements apart from the altered position of the screws, it would probably be objected that the second series of trials was made under different conditions from the first, and certainly there would be a new and grave element of doubt unavoidably introduced. When we consider that the setting of the main valves of a marine engine is originally carried out to give the best performance with those engines going ahead, which is their normal direction, our faith in M. Laubeuf's proposition is shaken, because the setting for backing, being for circumstances very important on occasion, but purely temporary and almost accidental, and giving a diminished power and inferior result, would hardly be fair.

For these, and other reasons, we incline to the belief that the question of the rotation of screw propellers can scarcely be settled theoretically by any amount of argument, nor practically by one or two experiments, or by tank trials; but only by actual working conducted over long periods and with vessels enough to exclude other considerations from the result, and to narrow the performance to the point sought. The question is one of some importance; will any Service be public spirited enough to carry out such investigations systematically and thoroughly, and until we have learned—what we all are in search of—the truth?

IMPROVEMENT IN THE INSTALLATION AND FITTING OF NAVAL MACHINERY.

By Lieutenant H. C. Dinger, U. S. Navy, Member.

SOME LINES OF IMPROVEMENT IN THE FITTING AND INSTALLATION OF NAVAL MACHINERY

The present and possible improvements in installation of naval machinery form a large field for study and investigation. New ideas are ever being evolved and improvements are constantly being brought in. A glance at some of the lines along which such improvements are to develop may be of interest.

In general, improvements manifest themselves along the lines of greater economy, simplicity, reliability, feasibility and usefulness.

ECONOMY.

To take up economy as regards fuel consumption: The importance of this does not lie in the cost of fuel, but in the saving of weight, space and labor and in the corresponding increase for power, carrying capacity and steaming radius, thus increasing the usefulness, endurance and reliability of a vessel.

Improvement in economy of fuel may be looked for in the following items:

1. The conversion of the heat of the fuel into the heat of steam or other fluid.

2. Conversion of the heat of the steam into mechanical energy.

3. The process of application of the mechanical energy obtained to the required purpose.

Improvements in economy obtained at the expense of great weight and space, or of reliability and simplicity, are very questionable.

FIRST STAGE.

The first stage, conversion of the heat of fuel into that of steam, is a question of boilers and the use of superheated steam; questions much discussed at present, and which are fields for development. Especially will superheating be of interest when turbine engines are brought into use more generally. In fact, with the use of turbines the field for study in the use of superheated steam is, as it were, freshly opened up by this new phase of steam application.

SECOND STAGE.

Taking the steam with its total heat, the object of the engineer is to get as much as possible of this heat into mechanical energy, and the largest possible percentage of this mechanical energy usefully applied. Improvements in this can be made by reducing existing losses and increasing the efficiency of the conversion.

RADIATION AND CONDUCTION.

The first loss will be in the radiation and conduction of the vessels containing the steam. This loss can be reduced by efficient lagging and by making as small as possible the radiating surfaces. Hence the design of piping systems whereby the piping is reduced to a minimum not only produces economy in weight, space and cost, but such reduction is a great factor in reducing loss of heat from the steam. It is also important to have piping so arranged that, when certain engines are not in use, only the shortest lengths required for those portions actually in use may be under steam.

LAGGING AND COVERING.

The qualities looked for in lagging are efficient non-conductivity, non-inflammability, lightness, ease in application and removal and durability. Preparations of magnesia and asbestos seem to meet these requirements as well as anything now known.

For naval work especial attention should be paid to the protective covering of lagging. Wood covering is inflammable, collects dirt, rots, chars, breaks and shrinks, being thus generally objectionable. For large surfaces Russia-iron covering is better.

It is light, durable, takes little space, is easily cleaned and will not burn. For places that are damp or subject to water galvanized iron is preferable. Other metal covering generally requires some form of paint to prevent corrosion. For pipe covering there are canvas and preparations known as "hard finish" on the lagging cement. This hard finish, as a rule, cracks and wears off and the lagging thus soon deteriorates. Canvas covering is quite efficient and durable, but collects dirt, requires painting and will burn. It is believed that, for other than small piping where canvas will have to be used, thin Russia iron with seams secured by brass screws would be the most desirable covering in every way. It has the advantages of durability, non-inflammability, ease of fitting, removal and cleaning.

FRICTION IN PIPES.

The steam, in passing through the pipes, valves, etc., encounters more or less frictional resistance, with its consequent waste of heat. When pipes are properly lagged and of sufficient area not to produce too much drop, no great loss results, but it is important to have the interior smooth, with few sharp bends and the lead as direct as possible.

LIQUEFACTION.

The losses due to liquefaction in cylinders are reduced by lagging, jacketing and by using dry or superheated steam. For the long-stroke, moderate-speed engine, steam jackets undoubtedly result in economy, this being especially so in the I.P. and L.P. cylinders. But for a short-stroke, high-speed engine, experiment has shown that jacketing is of doubtful value. The apparent reason for this is that the range of temperature is small, while the changes are rapid, and there is insufficient time between the changes to allow the jacket steam to do its work efficiently.

It may be said, therefore, that for a short-stroke, quick-moving, multiple-expansion engine, using a moderate pressure, no special economy is due to the use of the jacket. For engines of long stroke and moderate revolutions, jacketing will result in economy.

LEAKS.

With high-pressure steam the loss by leakage may be very great. The least amount of extra feed is about four tons per 1,000 H.P. per day, or in the neighborhood of .4 pounds per H.P. hour. This amount has often been exceeded on trial trips, and in service it is very likely that this is doubled or even trebled.

The main engines use about 15 pounds of water per H.P. per hour; if the leakage is .4 pounds per H.P. hour, here is a loss of 2.6 per cent. If this amount be trebled, as it often is, the loss may reach nearly 8 per cent. The possibilities of such great losses by ordinary leakage will at once turn attention to the exceeding care that should be given to securing tight joints. *The more joints, the more leakage.* Here, then, is one explanation for the difference in the steam economy of merchant and naval vessels. The merchant vessel has simple piping and few joints; the naval vessel has much complicated piping and many joints. Where the merchant vessel may use .2 pounds per H.P. hour extra feed the naval vessel may use .8 pounds, the difference being a loss of 1.3 per cent. in one case and of 5.2 per cent. in the other. The reduction of this loss lies in (1) reduction of piping; (2) properly made joints and stuffing boxes.

Perfect material for flange joints with high-pressure steam is a great desideratum that, as yet, has not been obtained. Corrugated copper gaskets are hard to fit and require considerable care in making, though when properly made they are tight. For small work they are apt to be badly made and to leak. Sheet-packing joints are more easily made, but do not last. Apparently the best thing now is to use copper gaskets for all but small work where strengthened sheet packing is to be used.

Stuffing-box packing has been greatly improved of late, and, with the best standard metallic packing for large work and spiral woven packing for small, general satisfaction may be obtained.

Boiler leaks are, of course, responsible for a large part of the extra feed, and the prevention of these leaks, or their remedies when they occur, requires even more skill and care than for leaks in pipe joints. Through these greater leakages with high-pres-

sure steam the theoretical advantage gained by the use of higher pressures is greatly reduced. With increased pressures leakage is considerably increased, even if joints are fairly good, while the greater labor, care and weight required for high pressure all detract from the advantages of its use. The question now follows: At what point does the greater economy due to increased pressure become balanced by the increased difficulties that are due to its use? The increase in economy due to high pressures is a decreasing ratio; the difficulty attending the design and installation of machinery and piping for its use is an increasing ratio. Just where lies this point of greatest advantage may be rather hard to determine, but for naval work, where lightness, general reliability and efficacy are such important factors, it is believed that this point has been overreached where pressure higher than 250 pounds above atmosphere is used.

CONDENSER.

The vacuum in the main condenser should, of course, be as high as possible, and for this reason all possible drains should be led to feed tanks or to the auxiliary condenser, where their bad effect on the vacuum is of less consequence. Every measure should be taken to maintain the highest vacuum in the main condensers and all steam used in the auxiliaries, the exhausts from which are always at comparatively high pressure, should be led to auxiliary condensers, feed heaters or evaporators, and not into the main condensers.

The greatest loss of heat is that which goes overboard with the circulating water. Within the limits of present knowledge and experience this great loss must still continue, but in its reduction there appears a wide field for improvement in economy.

HEAT LOSSES, HOW DIMINISHED.

These losses are being constantly diminished by the application of all the later developments of scientific engineering, but the possibilities for improvement are still great.

To reduce these losses we may have:

1. Feed heater using auxiliary steam as heating agent, and

used in place of auxiliary condenser, thus saving all heat formerly taken away by the auxiliary-condenser circulating water.

2. Feed water used for condensing steam from evaporator for make-up feed.

3. Auxiliary exhaust or exhaust from I.P. receiver used in evaporator.

In other words, reduce in every possible way the heat which otherwise would be taken away by the circulating sea water.

LIMITS OF ECONOMY.

The practical limit to steam economy would appear to be reached, aside from the questions of superheat, boilers, etc., when dry steam of high pressure is taken from the boilers and used through mechanically efficient expansion down to a vacuum of 28 inches in the main condenser, the feed water being returned to the boilers at as near the boiler temperature as is possible.

We may arrive at this most nearly by having a larger fraction of total steam, called A, pass through its greatest range, *i. e.*, down to lowest vacuum, and a smaller fraction B, used as economically as possible down to that temperature at which its latent heat can be most efficiently extracted by the feed water, and of such magnitude that this latent heat, with the small amount of sensible heat that might be utilized, are sufficient to raise the temperature of the feed water of A as near to the boiler temperature as is practicable. This temperature, due to practical considerations, will be about 200 to 220 degrees Fahrenheit. The percentage of these amounts, A and B, can be calculated approximately with ease. The latent heat at 212 degrees = 966 B.T.U.; temperature of air-pump discharge at 28 inches vacuum = 110 degrees Fahrenheit. Then A must be raised 110 degrees by the latent heat of B $\frac{966}{110} = 9$ approximately. Hence A should be about 90 per cent. and B about 10 per cent. of the total steam. This would then be the approximate relation for greatest economy. Since, however, there are heat losses by radiation, leaks, etc., it would very likely be somewhat more, say 11 or 12 per cent.

Now, certain auxiliaries, owing to their installation and other

governing circumstances, do not obtain the economical benefits of a long range of temperature. Notable among these are direct-acting pumps and small, simple engines. These simple engines, when using steam of 150 pounds to 200 pounds pressure, will be almost as economical when the pressure in the exhaust is about at atmosphere as when exhausting into a condenser having 15 to 20 inches vacuum. Therefore a reduction in the range of these auxiliaries, to produce a pressure in the exhaust slightly above the atmosphere, will cause them to use but little more steam.

If the exhaust of these auxiliaries were kept at about 222 degrees = 2 pounds above atmosphere, all this latent heat could be utilized in a feed heater.

The auxiliaries on a naval vessel require, on a rough average, about 15 per cent. of the total steam. Certain of the auxiliaries are of such nature that they can be fitted to operate advantageously under the greatest range of temperature produced by high pressure and good vacuum. This is especially true of dynamo engines, the dynamo plant being now of such size that economical engines can be installed. The dynamos will require one-fourth to one-third of the total 15 per cent. of steam used for auxiliaries, so that the remainder of the auxiliaries will use about 11 per cent. of the total steam under way, which, roughly, is enough to raise the feed water to about 220 degrees, Fahrenheit, if the exhaust is used for this purpose.

In port the dynamo and evaporator will use about 80 per cent. of total steam, there being a minimum use of feed pumps, steering engine, blowers, circulating and air pumps, and probably a greater use of electricity. If the dynamo engines have a separate condensing plant, and the other auxiliaries are used to heat feed water, there will be very nearly the looked-for relation. If the auxiliaries exhausting to the feed heater bring too much steam, some relieving device must be supplied. If the evaporators are fitted to use the auxiliary exhaust, they could utilize the surplus heat of the exhaust, or the relief on the feed heater could be adjusted so that the auxiliary or main condenser would take whatever surplus steam there might be. This is the system installed on late battleships.

By properly using the heat of the auxiliary exhaust in the feed heaters the necessity for fitting an auxiliary condenser for the engine room is removed, but for the purpose stated above one of small capacity should be fitted for use in port, though the main condenser could be utilized, provided stop valves were fitted in the main exhaust pipes.

DISTILLER CIRCULATING WATER.

Another saving of heat can be made from the circulating water of the distillers. The make-up feed is discharged either to the main condenser or through the distillers. In either case sea water takes away latent heat which is lost. The cold feed water might well be used for this purpose, especially for make-up feed. The simplest way would be to have the evaporator discharge into the feed tank, so that the make-up steam would be condensed by the feed coming from air pump, at the same time raising the temperature of the feed water. The feed tank would then act like a jet condenser for the steam for make-up feed from the evaporators. The necessity of having cold drinking water would require that a distiller having circulating sea water be used for supplying cooking and drinking water.

The make-up feed is about four tons per 1,000 I.H.P. per day. The consumption of steam at engines is about 15 pounds per I.H.P. per hour, or 36,000 pounds per 1,000 I.H.P. per day. Four tons = 8,960 pounds. Heat, latent and sensible, available for transmission in evaporator steam = 8,960 × 1,000 = 8,960,000 B.T.U. $\frac{8960000}{360000}$ = 24.7 degrees, or rise in temperature of feed water. The practical limits would probably be between 20 degrees and 30 degrees Fahrenheit, and the water would leave the feed tank at 110 + (20 degrees to 30 degrees) = 130 to 140 degrees Fahrenheit. These are temperatures at which the feed or hotwell pump can readily handle the water, and by this process the make-up feed has caused no loss of heat except that due to radiation, friction, etc.

THIRD STAGE.

We now come to the third division in which improvement may be looked for; *i. e.*, the process of transforming the me-

chanical energy derived from the steam into the useful energy of propelling the ship. Here losses are mainly due to friction.

VALVES AND PISTONS.

Starting from the main steam pipe, we have, first, the friction of valves and pistons. The use of piston valves with spring rings, and of slide valves with relief rings, has reduced the friction which might occur. The present difficulty in the use of spring rings, especially for H.P. pistons, is produced by steam entering the space at the back of the rings and setting them out hard against the cylinder. To prevent this, the rings are so fitted that they cannot expand beyond a certain limit which can be adjusted. Solid rings made to fit the cylinder exactly are also used. Another successful arrangement is a solid ring provided with a clamp lug and turned slightly large. Then a section is taken out to approximate the cylinder diameter; a solid dovetail clamp is put on and the ring turned to a neat fit, allowing no circular expansion whatever. When wear takes place, the clamp is slightly eased out, and a thin liner placed in the cut of the ring, thus increasing the diameter of the ring to make it tight. If these solid rings are properly cared for they should give good satisfaction. They may be removed and new ones fitted as soon as any wear shows. A great deal will depend upon proper adjustment, workmanship, material and lubrication.

As to materials, hard, close-grained cast iron, wearing on like material, gives the best surface for cylinder purposes. With good adjustment and proper care, cast-iron rings, cylinders and valve seats show a beautiful, hard, smooth-wearing surface, with no other lubrication than steam. When dry or superheated steam is used its lubricating value is reduced, and the wearing parts are apt to become dry as well as hot. The use of oil for internal lubrication is very objectionable in marine engines, but if dry, high-pressure, superheated steam, or jacketing, is used with great piston speed, some lubricant is a practical necessity.

It has been found from experience that pure flake graphite is a lubricant that will serve the purpose well. Graphite fills up the irregularities in the surfaces, making them very smooth, and by

the rubbing action they become hard and glassy. Graphite also remains on the surface, and is not easily carried away. It thus keeps the metallic surfaces from contact, and, by filling up small irregularities of surface, it also makes the sliding joint tight. It is not affected by any heat liable to be encountered, and does not possess the numerous deleterious effects of oil. Graphite can be fed into cylinders by being mixed with water or in its dry state. When vaselining cylinders, adding graphite to the vaseline will improve lubrication and insure smooth running.

STUFFING BOXES.

The next point where great frictional losses are encountered is at the various stuffing boxes of piston and valve rods. The amount of friction depends on the character and tightness of the packing used. Several forms of patent metallic packing seem to provide about all that can be expected. Those packings which make provision for the rods having a small amount of side play have especial merit in preventing wear on rods. In practice it is found that the glands need extra lubrication, which is supplied by swabbing the rods with a mixture of cylinder oil and graphite.

ENGINE BEARINGS.

The problem of the various engine bearings is one of design, adjustment and lubrication. The design must provide for proper materials, the lining metal must not be too soft and must be reasonably durable and able to withstand a material rise in temperature; sufficient area must be provided and an adequate supply of oil is necessary, while means should be provided for increasing this supply when necessary.

LOSS DUE TO PROPELLER.

The friction due to the surface of propellers is very considerable, and for that reason certain materials possess an advantage, such as the various tough and close-grained bronzes which have smooth surface and do not attract marine growth. The problem of pitch, blade surface and prevention of cavitation will affect very materially the efficiency of the propelling machinery. Appar-

ently the proper relation of these points can only be determined by investigation based on actual performance. While it is doubtful if any great improvement over present best practice may be expected, the ideal efficiency will be more nearly approached as constant research, study and experiment teach what to avoid or change. The investigations of Lieutenant C. W. Dyson, the results of which were published in the JOURNAL, May, 1903, Vol. XV, No. 2, very thoroughly point out such improvements derived from experience.

ARRANGEMENT AND DESIGN OF INSTALLATION.

It is here that the greatest practical improvement may be effected. The reliability and endurance of the machinery as a whole, and the ease with which it may be kept in the state of greatest efficiency and readiness for service, will depend upon the accessibility, simplicity and convenience of arrangement of its integral parts more than upon anything else. It is only by providing proper means for operating, overhauling and repairing that machinery can be kept ready to respond to the urgent call for highest power. Machinery installed on these principles may not look well on paper, but it will be ready for actual performance when called upon. The first reason that the machinery of the merchant marine is in a state of comparatively greater efficiency, when care and character of attendance is considered, is because of its greater simplicity. The machinery of a man-of-war should be the most durable and reliable; in fact, it is the most easily deranged. Fast packet boats, which have a regular run and a repair yard at each end of their trip, might be allowed more delicate and more intricate installations than they carry, but a man-of-war must rely upon internal resources and be able to do any service at any time. Just as the physical condition of the soldier is the keynote of battle strength or weakness, and as neither cripples nor men lacking physical strength are put in the ranks of fighting men, so, too, should reliability and endurance be considered in a man-of-war, while all delicate, untested and uncertain productions must be kept out of the line of battle.

THE ECONOMY OF WEIGHT, SPACE AND FUEL CONSUMPTION.

These are questions that ought to be considered fully when deciding the machinery which is to go into a ship. The general features have become pretty well established, although details will be improved from time to time.

The question of weight is the most important because the weight of machinery is limited by the displacement of the vessel. Space is limited by the necessary arrangement and subdivision of the hull, but, in a large measure, can be practically increased by intelligent utilization. Space may be very important in some places and very unimportant in others. Arrangements for its utilization should be made accordingly. It must also be borne in mind that space, *per se*, does not weigh anything and does not add to displacement.

Economy in fuel consumption is very important, not only for the saving in cost, but for the saving of the weight of fuel to be carried. When it is considered that the weight of fuel is generally about 20 per cent. of the displacement the importance of this is manifest.

The question of the system of installation of the various auxiliaries should be based on the above considerations as well as on the primary questions of adaptability, reliability and simplicity.

AUXILIARIES.

Auxiliaries seldom used or only intermittently used should be as light as possible and need not be very economical; the size allowed will depend largely on circumstances.

Auxiliaries in constant use should be as economical as possible and may be heavier, because in a very short time they use their weight in fuel.

Long piping in constant use with steam is very objectionable, owing to discomfort by heating confined spaces, space taken up, weight and loss by radiation.

Auxiliaries in distant parts of vessel should require as little attention as possible.

RELATIVE ADVANTAGES OF STEAM AND ELECTRIC DRIVE.

In deciding upon the advantages of steam, electric, pneumatic or hydraulic drive for auxiliaries in accord with above considerations we may reason as follows:

For general economy a good sized electric plant with economical engines will operate motors with perhaps a greater degree of economy than will steam used in small direct-acting steam engines, but at an increase in weight of 50 to 100 per cent. It will be more economical than either pneumatic or hydraulic drive and probably somewhat lighter. Therefore these systems of drive should be used only where their peculiar advantages overshadow the question of weight.

Steam has the advantage in lightness, electricity in adaptability and coal consumption. This is based on the supposition that an electric plant using as little as 20 pounds of steam per K. W. hour and having a practical service efficiency of transformation of 90 per cent. at dynamo and 70 to 80 per cent. at the motor can be obtained. So that by the electric drive a H.P. is delivered by motor with the consumption of about 25 to 30 pounds of steam per hour. This is considerably more economical than small steam engines, either simple or compound, operating from long lengths of piping. The best of such steam engines will use about 30 to 40 pounds of steam per H.P. hour.

Another basis for advantage of economy for electric drive is that in power transmission for shops the electric system has been found to be more economical than the steam system where there are small steam engines at each tool. However, where very small motors are used, the economy drops very considerably.

It is difficult to state concisely the relative economy in the various methods of drive in which the conditions vary so greatly and so irregularly, but, as a rule, the advocates of electric drive will point to the economy of a large installation with large motors and compare it with some very uneconomical steam installation on board ship. In the case of shop drive, the conditions are, however, quite alike.

Assuming these to be granted facts, such auxiliaries as venti-

lating blowers and ice machines should be operated by electricity, since other advantages of electrical drive come in, such as less attendance, no heating of crew spaces by steam piping and greater speed ranges for blowers.

The steering engine, being in constant operation under way, may also be operated by electricity, provided the superior advantages of electricity in reliability and ease in manipulation are proved and any great excess in weight is prevented. Its location directly beneath living quarters is an added reason to dispense with the steam piping.

The windlass is used only for short periods, but it must be heavy in structure to provide for the rough usage it receives. Steam for the windlass motive power offers the least additional weight and is at present more reliable for this purpose than other forms of drive. It has, however, the great disadvantage of long leads of steam and exhaust pipes, with consequent heating of living space.

Forced-draft blowers are, as a rule, used only intermittently, and should be operated by steam turbines to save weight and to obtain the necessary speed of revolution. They are generally installed in places most unsuitable for electrical apparatus. It must be said, however, that a turbine especially fitted for this work has yet to be developed.

Boat and crane winches present the question of whether greater weight is to be preferred to heating of compartments, danger of pipes being shot away and longer time being needed to start machines. Where the lead of piping is long, the advantages for electrical drive are greater; where the lead is short, steam gains. Steam drive would probably be more reliable, but the electric drive more handy.

Ammunition hoists and gun-mount motors, owing to the objection of piping, greater handiness and efficient control furnished by the electric drive, should be and are now almost exclusively operated by electric motors. These are in operation only for short periods. The question of economy does not enter largely, but such electric installation means an addition of weight.

The appropriateness of operating by electricity any of the aux-

iliaries in the engine rooms, except some special ones where heating may be extremely objectionable, is very questionable.

All electrical installation has an excess of weight over steam, and only when the system of electric drive is more economical, especially in auxiliaries in operation most of the time, or where the electric system offers paramount advantages in handiness or peculiar efficiency for the purpose in question, as in turret motors, ammunition hoists and ventilating blowers, should electric installation be used.

To sum up: For driving auxiliaries outside of engine room, we have:

By steam—Windlass, forced-draft blowers (turbine), dynamo engines (turbine).

By electricity—Ventilating blowers, ammunition hoists, turret and gun-mount motors, ice machine, workshop motor.

By steam or electricity, depending on conditions of service and installation—Steering engine, boat cranes, deck and coaling winches.

The electric generators would then be operated by steam turbines, which, in a few years, will probably have reached such development that their advantages over reciprocating engines will be as great for the smaller installations required on board ship as the large installations on shore now possess. Such an installation must have its own condenser, and perhaps a special air pump, in order to obtain the high vacuum necessary for best operation. The development of the alternating current on board ship will greatly advance the advantages for electric drive. But until this is developed, which will require time, our conclusions must be drawn from the continuous-current motor.

AUXILIARY INSTALLATION.

Auxiliaries should be installed with a view to securing reliability, handiness, economy and general all-around efficiency.

First: The most important and essential auxiliaries should be provided for, and here the most efficient for the purpose, though not necessarily the lightest and most compact, should be installed.

The really indispensable auxiliaries are not numerous, and if, through lack of space, those not absolutely essential can not be installed to perform efficiently and reliably, they would better be omitted altogether from the design. On the other hand, weight and space must be duly considered in the installation of auxiliaries, and no unnecessarily heavy and bulky auxiliaries should be installed. Often it is apparent that the main engine's weights are cut down by light design, while the weight of many auxiliaries seems to have received too little consideration.

Second: Avoid unnecessary or non-essential installations, and unnecessary duplication, or duplication of units, the importance of which does not compensate for the disadvantages entailed by their installation.

Unnecessary or ill-advised duplication and elaboration adds enormously to the weight, occupies valuable space, adds greatly to the labor of keeping machinery in order, and often prevents a handy arrangement.

Numerous duplicate systems no doubt appear well on paper and to the theorist, but it is only too frequently true, owing to the disuse of the alternative systems, that they are valueless when brought to the test. Duplicate systems are valueless unless each duplicate part can be made thoroughly efficient by itself. This would entail so much extra weight, space and care that the provision against an accident would be worse than the possibility of it. To guard against every possible derangement or adverse happening is practically impossible, and an endeavor to do so not only leads to overloading a ship with various devices of questionable utility, but serves to make the essential features less perfect and reliable. Practical perfection will be found in a system of such simplicity, strength, reliability and good workmanship that the chances for derangement are reduced to a minimum. Making elaborate provisions for derangement appears to be starting at the wrong end and predicting weaknesses which should not exist.

Efficient duplication of certain important features is a necessity, but further complication only detracts from real security, while the increase in weight, space, attendance and cost is greatly disproportionate to the remotely possible service rendered.

THE FACTOR OF UTILITY.

Every device put on board a man-of-war should have a definite relative utility in contributing to the fighting efficiency of the vessel, measured by comparison of its weight, space occupied, and the attention it requires to operate it. Any device, the utility of which, when thus compared, is low, must be omitted from the design to allow those of greater utility to be installed.

If this be rigorously followed out, much space for fitting essential features will be found, and, though the process may remove many things hallowed by tradition and sentiment, it will add certainly to the fighting efficiency of the vessel.

Many of the so-called automatic devices that have been and are still urged for installation on naval vessels are in fact only added complication. As a rule, the matters that they are designed to regulate do not really require their regulation, and most of such devices show their inutility and inefficiency as early as the trial trip. When we sum up the weight and cost of these fittings, the space they occupy and their interference with other essential parts, remembering that they are frequently unreliable, unnecessary and cumbersome, we must realize the futility of retaining them in our vessels.

Among the devices that have demonstrated their inefficiency, and for which no real need exists on board ship, are:

Water and fire alarms for compartments and bunkers; automatic feed regulators on practically all types of boilers; reducing valves on main steam line; float regulating valves for governing throttles of auxiliaries; superheaters in connection with reciprocating engines; feed heaters using flue gases as heating agent; air-heating systems where increased weight and space are considered; nearly all automatic devices for closing valves and doors in case of accident; automatic regulators operated by change in temperature.

PLURALITY OF APPURTENANCES THAT MAY BE REDUCED.

Pumps: Not more than two main feed, one in each engine room; one auxiliary feed, fire and bilge in each boiler compartment; one fire and bilge in each engine room; also one sanitary

water-service and distiller circulating pump, and a fresh-water distributing pump in each engine room. In case suction feed heaters are used, a hotwell pump for each, the fresh-water pump being dispensed with.

Auxiliary condensers: Only one for engine rooms is needed, especially for smaller ships; two are not necessary, as the main condensers can always be used in case of breakdown. In large vessels, the dynamo room should have its own condenser.

Feed heaters: Not more than two.

Dynamos: The number of units in the electric generating plant of many vessels might be reduced with advantage, larger units being used, and a suitable rearrangement of space being provided.

Evaporators: Their number should be kept down and their size increased, suitable space being supplied to install efficient types.

SIMPLICITY OF FITTINGS.

All the fittings about naval vessels should be as simple as efficiency permits, and, wherever possible, of a standard type, so that the necessity for carrying numerous spares may be avoided. In considering this question, the fixed rule should be to install as few fittings as possible, and not, as sometimes seems to be the case, to put in as many as can be crowded in at great expense in future overhauling.

It should be recognized that a ship of war is not designed primarily as an experimental station, and that a great many data recording instruments and devices for obtaining special indication are of no value in enhancing her performance. It is not imperative to know to a fraction the steam pressures or temperature for ordinary running. General and specific data obtained for the purposes of design should be collected with that special end in view, and special instruments should be fitted for recording and taking this data to any degree of accuracy desired; but to fit an elaborate outfit for each vessel where, in most cases, it is not used at all, and where the personnel of the vessel is not trained in its use, is extremely ill advised.

Sight-feed lubricators for internal lubrication on vertical cyl-

inders are not needed, and, by many engineers, are removed soon after the vessel is put in commission. If, by chance, it becomes necessary to introduce oil, it can be done through the indicator cocks for main cylinders; valve chests in which there is a possibility of oil being needed may be supplied with a small, simple oil cup, the elaborate affairs generally installed being unnecessary.

Metallic dial thermometers, of the quality usually fitted, are rarely reliable for any length of time. In important places fixed mercurial thermometers should be placed, but a pet-cock and an ordinary portable thermometer will serve all practical purposes for testing water temperatures.

FACILITIES FOR REPAIR AND OVERHAUL.

No qualities in the design and installation of marine machinery are more important than those which provide accessibility and facility for repairing and overhauling it. Judging from various examples in existence, however, these seem to have received but minor consideration. More careful thought given to this question when the designs are worked out and when the machinery is being installed might often save an enormous amount of work during later service.

Some points in this connection are: Facilities for removing cylinder covers, jacks and trolleys for handling them quickly and easily, and space for lifting them; jack bolts and eye bolts; marks and guides to show when parts are brought into proper place; keys formed with nibs to facilitate their removal; valves installed so that their bonnets can be removed and glands packed.

Bonnets that must be removed to enable examination or repairs to be made should require the breaking of as few joints as possible; this applies to condenser heads, covers of attached air pumps, feed heaters, etc.

Brasses and other heavy parts liable to frequent removal should be tapped for eye bolts.

Feed tanks should be arranged so that they are easily accessible for cleaning.

Boilers, condensers, feed heaters, evaporators, etc., should be arranged so that there is ample room for the withdrawal of tubes.

If there is not sufficient room to install certain auxiliaries so that they can be properly overhauled, they would better be left out altogether, for, as they are only overhauled with difficulty, they will very likely soon be out of use.

QUESTION OF WEIGHT NOT TO BE CONFINED TO MACHINERY.

Effort in the direction of saving of weight should not be confined to the boilers and machinery alone. Greater results should be looked for in other parts of the ship, because there we find a larger field.

It is an ever apparent fact that many of the various fittings on a ship are made uselessly, unnecessarily and unhandily heavy and large, so that in many cases they not only have this great objection of weight, but by reason of their clumsy construction are unhandy for the very purpose for which they are designed. There are instances where the anchor davits on one of two similar vessels are fully twice as heavy as on the other, though the anchors are of the same weight. The same is true of boat cranes and davits. Unnecessary bulkheads which do not add to the strength or watertightness may be observed. Elaborate and heavy ornamental plates and fittings may be seen, heavy cast name plates, solid hand rails and unnecessary rails.

Considerable weight is often added for the sake of appearance. If the appearance can be improved without a sacrifice of the essential things, let us have the trimmest ships we may ; but the prostitution of valuable weight to mere appearance certainly should not be tolerated. Many items taken separately may seem unimportant and be regarded as mere nothings, but, when taken in the aggregate, they may amount in weight to that of the coal for several days' steaming, to a number of additional rounds of ammunition for the battery, or to a sufficient addition to the boiler installation to develop several hundred more horsepower.

Nothing should be made too light to stand the hard knocks of

the most rigorous service, but all excess weight beyond these service requirements and all useless weight should be kept out.

A few examples in which there is a field for the reduction of weight are:

Fitting of stockless anchors, which, by running into hawse pipes, dispense with the weight of bill boards and davits.

Making all rails and stanchions hollow.

Designing all boat davits, cranes, etc., of such section as will insure continued strength and lightness.

Dispensing with too elaborate subdivision, and with the fitting of unnecessary air locks, doors, etc.

Simplifying piping and drainage systems, which are often altogether too elaborate.

It is a fact that great elaboration and complication often exist in relatively unimportant installations because their design has not received as much attention as more important details. The result is that these lesser matters require, in service, greatly disproportionate weight, space and attention. It is, therefore, axiomatic that every detail entering into the construction of a naval vessel must receive careful consideration, not so much by reason of its own importance as for its effect on other matters.

Fittings, the uses of which have been outlived, should be dispensed with and not allowed to remain in the design on the remote possibility of being of some use at some time. There is room only for actually necessary equipment, and we must have one thing or the other, not both in a less efficient or reliable state.

The underlying thought of a successful installation must be a recognition and knowledge of the work each unit must do, and the service conditions under which that work is done. Facility of installation in a building yard is of small importance compared with facility of operation and repair in strenuous service.

One important fact that must not be overlooked in considering this matter is this—that the trial-trip results, which are the culmination of the builder's interest in the ship, are not necessarily those which give the ship a value to the Service when in commission.

ON THE INFLUENCE OF INWARD AND OUTWARD-ROTATING PROPELLERS ON THE MANEUVERING QUALITY OF TWIN-SCREW VESSELS.

TRANSLATED BY REAR ADMIRAL C. R. ROELKER, U. S. NAVY, MEMBER.

[From "Mittielungen aus dem Gebiete des Seewesens," Vol. XXXII, No. 11, January 15, 1904.]

Professional journals have lately frequently discussed the question: "What influence on the turning power of the vessel is exerted by the direction in which the propellers rotate?" that is, whether in going ahead, considering the motion from below, they rotate upwards towards the side of the vessel or away from it. In the year 1898 the well-known investigator, R. E. Froude, delivered a lecture before the Institution of Naval Architects on the results of comparative tests with towing models as to the effect of direction of rotation of the propellers in twin-screw vessels on the speed of different classes of vessels. He stated that, from a large number of such towing experiments made at Haslar with models of different classes of vessels, the conclusion might be drawn that the differences in results were unimportant and rather in favor of inward-turning propellers.

Among other speakers, during the discussion of the above-mentioned lecture, the former British Chief Constructor, Sir William White, mentioned likewise that, according to his experience, the steering qualities of vessels were not impaired by inward-turning propellers. However, he had probably in view only the steering of vessels underway.

In consequence of this lecture similar experiments were made at the towing-model basin at Spezia, with models of different classes of vessels and different propellers, in order to investigate the influence of the direction of rotation of the same upon their propelling efficiency; the results were published in the "Rivista

Marittima," Vol. VIII–IX, of the year 1903, by the Italian Marine Engineer Pecoraro. By these experiments in Spezia it was clearly established, in the first place, that the location of the propellers relatively to the hull of the vessel has an influence upon the co-efficients of efficiency depending upon the different directions of rotation, and that this influence is the more marked the nearer the propellers are situated to the hull of the vessel. Besides, it was found that, contrary to the results of the Froude experiments, the model experiments at Spezia exhibited a more favorable co-efficient of efficiency for the outward-turning propellers compared with the inward-turning ones, although the difference was for normal proportions practically unimportant. In conclusion, Engineer Pecoraro expresses the opinion that, from the results of the large number of experiments, no general law can be established for the preferability of the one over the other arrangement, and that it is desirable to determine by experiment in each individual case the most favorable conditions for the inward or outward turning of the propellers.

Last year the English Admiral, Sir J. A. Hopkins, referring to a lecture in the "United Service Institution," raised again the question: "Should the propellers of future designs of battleships turn inwards or outwards?" making, in this connection, the following remarks:

"My own experience of two ships in the Mediterranean is against the screws turning inward, as it handicapped the ships' turning with no 'way on' to such an extent as almost to make turning on their heels without 'way on' impossible; and many of you will call to mind, with the outward-revolving propellers, how the good ship under you steadily swung round the compass without moving ahead or astern by simply revolving the screws in opposite directions, and one always felt what a pull it was in close harbors or tight places."

In the discussion following the lecture several speakers referred to this question. Admiral Sir Bowden-Smith remarked that he would not sacrifice the ship's turning power for a slight increase in speed, if really vessels with inboard-rotating propellers could not be turned so readily with no "way on."

Rear Admiral Lord Charles Beresford expresses similar views, declaring that he agrees entirely with the remarks of Sir John Hopkins. According to his opinion, "the inward screw does militate against the handiness of the ship when going in and out of harbor on ordinary active service, and it is a hundred chances to one in an action that a skillful captain who knows his ship absolutely might sink an adversary, or might avoid being sunk, if he had outward-turning screws. Probably the inward-turning screws do produce a little extra speed. The real reason for the inward-turning screw was to give the engineer a little better control over his engines. That is a very good point and a very serious point, but everything to do with the ship is a compromise, and you most certainly ought never to sacrifice the fighting efficiency so that the captain is unable to do his level best with the ship under any consideration whatever."

A different view was expressed by Rear Admiral A. C. Parr, who spoke as follows:

"With regard to the turning power of the vessel with the screws turning inwards, I have often heard it said that the vessels do not turn as well as with those turning outwards; and, having been recently in a position to make certain trials with regard to it, I thought it was advisable to do so. I did not find, with my own experience of outward-turning screws, that the vessel always turned quite as easily as would seem to be indicated by the paper.

"The first vessel that I made experiments with was the new Royal Yacht. I may say that with her there was no difficulty in going in and out of harbor, taking her into Plymouth Sound, picking up buoys, slipping from buoys, and taking her out again. But I thought it advisable to try her, so we put buoys down alongside the ship; she was stopped dead and then turned through 90 degrees one way. After she was stopped dead we turned her through 90 degrees the other way, and there was not the smallest difficulty of any sort or description. She went smoothly and quietly, and never held up at all. That was in calm weather.

"The next ship tried was the *Glory*. On that occasion there

was a fresh breeze blowing—nearly 4, I should think—so much that I doubted whether she would have turned at all, even with the inward-turning ones. However, she exceeded my expectations. When she was with the wind abeam, and stopped dead, with the engines working with a speed of about 12 knots ahead and astern, she turned slowly, but she turned steadily, and never stopped, though she hung a little at times. She completed the 90 degrees up to the wind in, I think something over a quarter of an hour. Of course, that was a long time, but she did it, and she did it without much trouble. In turning the other way, when falling off, she did it in very much quicker time. The *Aboukir*, I think, was also tried with similar results."

Admiral Freemantle agreed with the view of Rear Admiral Parr, stating that, according to his experience, there was not a great deal of difference in the screws turning inwards or outwards. The difficulty would come in where there is a breeze of wind or a nasty current on the bow—a nasty tide. Under these circumstances a ship, whether with screws turning inwards or turning outwards, would not generally turn without "way on."

He considered the reason, given by Lord Charles Beresford, why the screws turn inward a very important one, namely, that the engineers may be able to control the engines with much greater facility at starting and stopping and on every other occasion.

In his closing speech Admiral Hopkins weakened his original assertion in so far that he did not mean to assert unqualifiedly that in-turning screws impaired the maneuvering power of battleships. His contention was that he had found ships with in-turning screws difficult to maneuver, and that he invited expression of opinion from experts in the British Navy upon this question.

Although his experiences did not agree with those of Admiral Parr, he would be pleased if he might be converted from his own views, for it was depressing to see all the new ships, without exception, being fitted with in-turning screws, with the main object of obtaining a slight increase of speed. He agreed fully with the view of Lord Charles Beresford that to sacrifice to the

smallest extent the turning powers of ships at any speed whatever would be probably paying dear for it.

This discussion, an extract of which has been here given, induced the American Engineer-in-Chief, Rear Admiral George W. Melville, lately retired, to express his opinion on the subject. He states that the question is not a new one. Even twenty years ago the subject was discussed, and as soon as a member of the marine profession brings up a new phase of the question the discussion commences anew.

The main importance of the question was decided many years ago to rest on the influence of the arrangement of the propellers on the vessel's speed. Experiments and practice showed that, if there was any question of advantage of one installation over the other, it was to be found only on the side of the inboard-turning propellers, and that, too, independent of technical grounds which also speak for this manner of the turning direction of the propeller.

The question which installation gives the best maneuvering qualities was likewise repeatedly discussed. There are no data showing that, with deep-draught vessels, one or the other arrangement of propellers is more favorable for maneuvering purposes. Marine engineers were more favorably inclined to the installation of inboard-turning propellers, only because weighty technical reasons speak in their favor, while the advantages of outboard-turning propellers came nowhere near them.

With special regard to the remarks of Admiral Hopkins about the "good old ships with outboard-turning propellers," Admiral Melville mentions that in these vessels the proportion of breadth to length was very great compared with modern types of vessels. That the maneuvering qualities of battleships had deteriorated was a result of the increase of displacement of modern vessels, as well as the ratio of length to breadth, and not because the screws were turning inboard.

The "Scientific American" contains an article in which the American Naval Constructor, Taylor, discusses the advantage of outboard-turning propellers over inboard-turning ones in regard to the maneuvering ability of vessels when at rest. He says:

"It is known that, as ordinarily fitted, the effect of a screw working when the vessel has no steerage way is to throw the stern transversely in the direction in which the upper blades of the screw are moving. This is because the upper blade does not get so good a grip on the water, and the transverse motion of the water, acted on by the upper blades, is more obstructed by the ship than that of the water acted on by the lower blades. In line with this theory, the arrows within the screw circles in the diagrams show the direction of revolution of the screws. The solid arrows above and below the circles indicate the transverse forces acting on the ship, the upper blades in each case, in Fig. 1, pulling the stern to starboard, and, in Fig. 2, pulling it to port; the lower blades pulling the stern to port in Fig. 1 and to starboard in Fig. 2. The net result is a transverse force $F_2 + F_4 - F_1 - F_3$ which pulls the stern to port in Fig. 1 and to starboard in Fig. 2. The final resultant, then, of the transverse forces and thrusts developed by the screws is, in Fig. 1, the difference of two forces, and necessarily less than either, while in Fig. 2 it is the sum of two forces, and necessarily greater than either.

"If the propeller shafts diverge as they proceed aft from the engine, each upper blade meets the water at a smaller angle in Fig. 1 and at a greater angle in Fig. 2 than it would if the shafts were parallel; while each lower blade meets the water at a greater angle in Fig. 1 and at a smaller angle in Fig. 2. The dotted arrows outside the circles indicate the resulting changes in the transverse forces, and it is evident that the transverse forces acting against the screw thrusts are, in Fig. 1, strengthened; while the transverse forces acting to help the screw thrusts are, in Fig. 2, weakened.

"The conclusions to be drawn from the above are: First, that in-turning screws reduce or nullify entirely the maneuvering powers under engines alone of twin-screw ships, when they have no steerage way; secondly, that shafts diverging abaft the engines are inferior, as regards maneuvering, to parallel shafts, and shafts converging from the engines are superior in this respect to parallel shafts."

DIAGRAM OF THE RELATIVE EFFECT OF INBOARD AND OUTBOARD-TURNING PROPELLERS.

FIG. 1.

Inboard-turning propellers; aft, looking forward.
Starboard propeller turning ahead.
Port propeller turning astern.
Ship without motion.

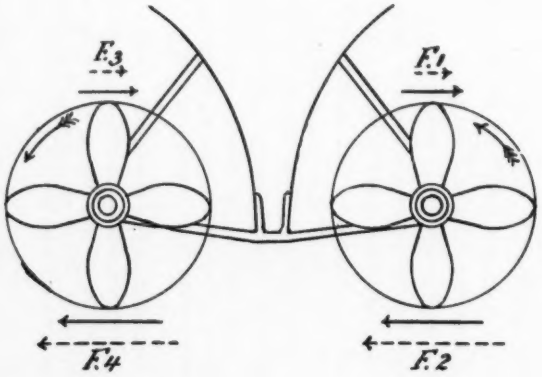
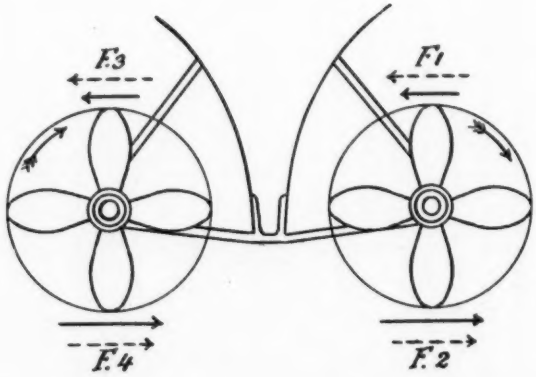


FIG. 2.

Outboard-turning propellers; aft, looking forward.
Starboard propeller turning ahead.
Port propeller turning astern.
Ship without motion.



The following information may be added here: The deviations of the axes of propeller shafts from a line paralled to the keel are in practice insignificant. The following examples are taken from vessels of the Austrian Navy:

Type, *Kaiser Franz Josef I*, degrees, ... ¼
Type, *Kaiserin und Koenigin Maria Theresa*, degrees, ½
Type, *Habsbung* and type *Erzherzog Karl*, degrees, . 1
Type, *Zenta*, degrees, ... 1½
Type, *Leopard*, degrees, ... 2

Experiments made at the Imperial Austrian Marine Arsenal with models of simple construction have proved with certainty that the divergence or convergence of shafts of twin-screw vessels, within the usual limits of practice, is of very slight influence upon the steering qualities of vessels.

As the above-cited views of several professional men do not permit us to form an opinion on this subject which is free from all objections, the "Marine Section" of the Imperial Austrian War Department, in view of the importance of the question since our own new battleships are all fitted with inboard-turning propellers, ordered experiments to be made which should give reliable information on this subject.

The *Leopard*, a vessel of the Austrian Navy, was placed at the disposition of the Trial Board, and the program of the experiments consisted in progressive-speed trials to obtain data for speed curves, and a number of turning maneuvers, first with normally fitted outboard turning propellers, then with the same propellers changed so that both turned inboard in going ahead.

As the results of these experiments will no doubt be of interest to professional circles, they are given below.

The main data of the *Leopard* are as follows:

Length on load-water line, feet and inches	234- 3
Extreme breadth on load-water line, feet	34
Ratio, L ÷ B	6.6
Draught amidships, feet and inches	13- 7⅝
forward, feet and inches	11- 7¾
aft, feet and inches	15- 7
Corresponding displacement, tons 2,240 pounds	1,490.7
Wetted surface, square feet	9,149.65

Immersed longitudinal section, square feet	3,124.875
Area of unbalanced rudder, square feet	64.69
Maximum angle of rudder, starboard, degrees	27
port, degrees	25
Screw data, three-bladed propellers:	
Diameter, feet and inches	12– 6
Pitch, feet	17.986
Developed area of blades, each screw, square feet	51.991
Area of screw circle, each screw, square feet	122.72
Distance between centers of screws, feet and inches	15– $2\frac{5}{8}$

The bottom of the vessel was newly painted before the experiments, so that the hull of the vessel was smooth. The experiments were made first with inboard-turning, then with outboard-turning propellers, and, in both cases the weather conditions were favorable and similar. Force of wind, 1–2. Sea, smooth.

The number of turns of engines was regulated so that the corresponding speed did not exceed 13 knots, for the purpose of not straining them in backing.

1. *Influence of direction of turning of propellers upon the speed of vessel.*

Inboard-turning screws.			Outboard-turning screws.		
Direction.	Rev. per min.	Speed in nautical miles.	Direction.	Rev. per min.	Speed in nautical miles.
Mean of two runs in opposite directions	60.21	8.89	Mean of two runs in opposite directions	59.55	8.76
	71.22	10.48		74.55	10.88
	79.45	11.65		89.79	12.83
	90.30	12.98			

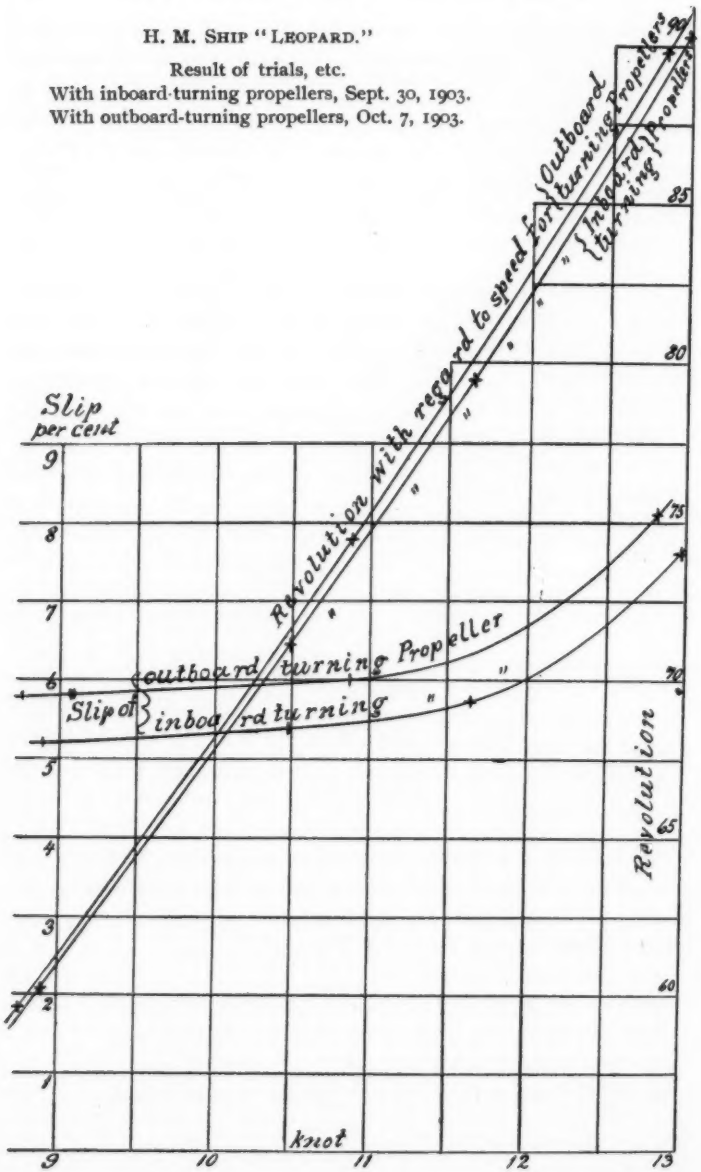
An examination of the speed curves constructed from the results of the trial data will show that the arrangement of inboard-turning propellers gives for equal number of revolutions of engines a slight increase of speed of vessel.

The difference is as follows:

90 revolutions, 0.085 knots, or .66 per cent. of speed.
80 revolutions, 0.095 knots, or .81 per cent. of speed.
70 revolutions, 0.055 knots, or .53 per cent. of speed.
60 revolutions, 0.050 knots, or .56 per cent. of speed.

H. M. SHIP "LEOPARD."

Result of trials, etc.
With inboard-turning propellers, Sept. 30, 1903.
With outboard-turning propellers, Oct. 7, 1903.



This difference is very slight, and at higher speeds of revolution would probably decrease.

II. *Influence on maneuvering qualities while under way.*

The mean results of observation were as follows:

1. *Vessel going ahead with 90 revolutions. Rudder hard over.*

Arrangement of propellers.	Speed on course, knots.	Rudder angle.	Rev. per min. during turning.		Time from order given to completion of quadrant.				Diam. of Turning circle, ft.
			Out-turning screws.	In-turning screws	1	2	3	4	
					m. s.	*m. s.*	*m. s.*	*m. s.*	
Inboard, I	12.95	26°	84.7	82.1	1 29½	2 56	4 25½	5 51	1991.5
Outboard, O	12.86	26°	88.3	82.5	1 31½	2 55½	4 22½	5 50½	2093.2

The time required to complete the turning is therefore practically the same for both installations. With Installation I the number of revolutions of screws appears to be less influenced (especially in the case of the out-board one) by the position of rudder; this is also made apparent by the greater diameter of the turning circle.

2. *Vessel going ahead with 90 revolutions. Port engine suddenly backed with 90 revolutions. Rudder amidships.*

Arrangement of propellers.	Rev. per min. during turning.		Time from issuing of command to completion of quadrant.				Diam. of turning circle, feet.
	Port eng.	Stbd. eng.	1	2	3	4	
			m. s.	*m. s.*	*m. s.*	*m. s.*	
Inboard, I	.....	.....	1 38	3 13	4 41	6 12	918.6
Outboard, O	80.9	87.8	1 23	2 39	3 56	5 12	902.2

It appears that the turning circle is practically the same with both arrangements of screws; but with the "outboard-turning" screws (O), about 16 per cent. less time than with the "inboard-turning" ones (I).

3. *Vessel going ahead with 90 revolutions. Port engine suddenly backed with 90 revolutions, and rudder put over hard aport.*

Arrangement of Propellers.	Rev. per min. during turning.		Time from issuing of command to completion of quadrant.								Diam. of turning circle, feet.
	Port eng.	Stbd. eng.	1		2		3		4		
			m.	*s.*	*m.*	*s.*	*m.*	*s.*	*m.*	*s.*	
Inboard, I.....	.....	.....	1	12	2	30	3	50	5	17	610.2
Outboard, O.....	77.4	83.5	1	10	2	18	3	17	4	17	682.4

The arrangement of screws I gave a turning circle about 10 per cent. smaller, but arrangement O required less time, varying from 3 per cent. to 19 per cent. for the turning.

III. Influence on turning power from at *rest.*

1. *When using greater engine power (70–90 revolutions).*

Revolutions per min., screws working		Time required to turn 8 points.									
		Rudder amidships.				Rudder on side of backing screw.				Rudder on side of ahead screw.			
back.	ahead.	I		O		I		O		I		O	
		m.	*s.*	*m.*	*s.*	*m.*	*s.*	*m.*	*s.*	*m.*	*s.*	*m.*	*s.*
80	90	1	53	1	45	1	36	1	42	3	26	3	10
90	80	1	58	1	55	1	50	1	43	3	01	5	17
90	70	2	02	2	44	1	47	1	52	2	19	4	15
90	60	3	25	3	26	3	50	2	06	3	45	6	17

Note.—I = inboard-turning propeller; O = outboard-turning propeller.

The most favorable results were obtained with both arrangements of screws with rudder amidships as well as when placed on side of backing screw, when one side worked ahead with 90 revolutions, and the other one backed with 80 revolutions. With both arrangements of screws there was a slight increase of speed ahead. The differences of time of turning are very insignificant.

With rudder amidships: 1 minute 45 seconds with O, against 1 minute 53 seconds with I.

With rudder on side of backing screw: 1 minute 42 seconds with O, against 1 minute 36 seconds with I.

The most unfavorable results were obtained with 60 revolutions ahead and 90 revolutions backing, *i. e.*, with the preponderating power in the backing engine. Omitting these observations, and the practically worthless one where the rudder was placed on the side of the screw working ahead, the mean results are as follows:

Arrangement of propellers.	Rudder.	
	Amidships.	On side of backing propellers.
	m. s.	m. s.
Inboard, I.....	1 58	1 44
Outboard, O.....	2 8	1 46

Consequently the arrangement, I, with inboard-turning propellers, has given somewhat more favorable results, but the differences are so slight that they have no practical value.

2. *When using less engine power (30–50 revolutions).*

Revs. per min., screws working		Time required for turning 8 points.					
		Rudder amidships.		Rudder on side of backing screw.		Rudder on side of going-ahead screw.	
back.	ahead.	I	O	I	O	I	O
		m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
40	50	3 45	2 56	2 24	2 29	4 18	5 6
50	40	3 57	3 21	3 1	2 54	4 40	5 48
50	30	4 54	4 28	4 6	6 37	4 52	6 5

Note.—I = inboard-turning propeller; O = outboard-turning propeller.

The most favorable results were obtained when the screw working ahead (50 revolutions ahead, 40 revolutions back) preponderated, and when the rudder was placed on the side of the backing screw when the vessel still had a slight ahead motion.

The difference of time of turning is very slight (2 minutes 24 seconds, with O, against 2 minutes 29 seconds, with I) and practically unimportant.

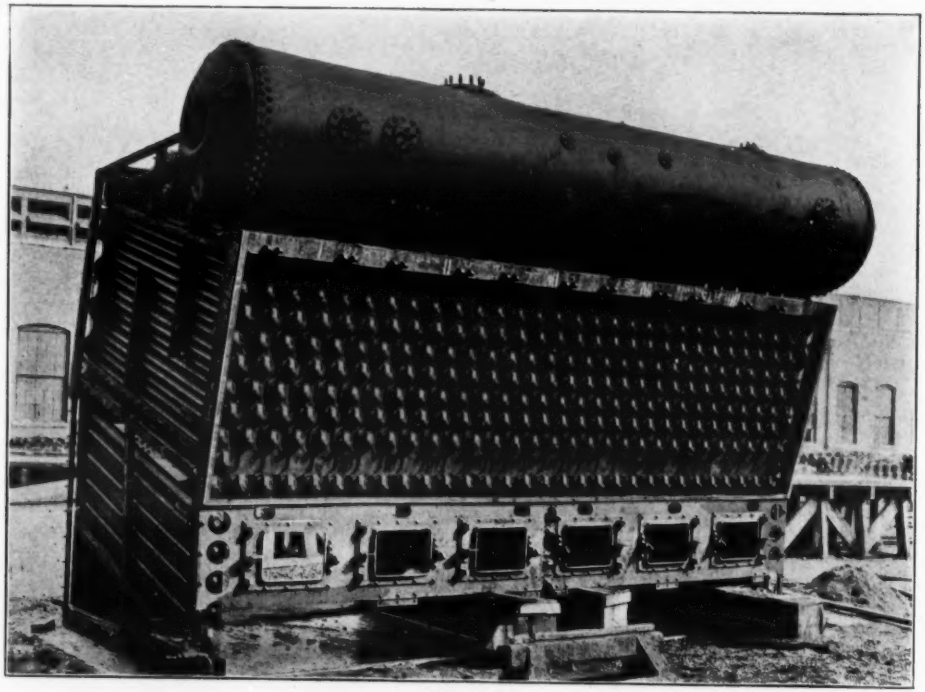
The most unfavorable result was produced with 30 revolutions

ahead and 50 revolutions backing, consequently with the backing engine preponderating.

FINAL DEDUCTION.

The experiments made with the *Leopard* have shown that inboard-turning screws give slightly better results as to speed—although the increase of speed is extremely small—and are of equal efficiency in steering while underway and in turning from a state of rest, and are only less effective when the vessel is turned by one engine being suddenly reversed and the rudder laid over, as far as time of turning is concerned, but not to turning circle. With modern large cruisers and battleships, with relatively much smaller diameter and pitch of screws compared with size of vessels, the influence of turning direction of screws will be doubtless even more trifling, and there is, consequently, no reason for abandoning the customary arrangement of screws with upper blades turning inboard while going ahead, which gives certain advantages regarding the easier communication between the two engine rooms, arrangement of ladders and signalling apparatus, better accessibility and attendance of machinery, and simpler installation of steam piping.

The inferior maneuvering qualities of modern vessels, insisted upon by several people, are not, or only in a very small measure, to be ascribed to inboard-turning screws, but rather to the fact that they are designed for higher speeds, and therefore must be built larger; and that, in order to bring the weight of machinery within prescribed limits, high piston speed, and consequently screws of relatively small diameter and pitch, have to be used. It does not appear practicable to select these elements of construction with regard to better turning qualities of the vessel from a state of rest, but it lies with the commanding officer to diminish the time required for maneuvers by an energetic use of the engine power; in other words, by increasing the number of revolutions for this purpose.



BABCOCK & WILCOX BOILER FOR U. S. BATTLESHIP "NEBRASKA." CASING REMOVED.

EVAPORATIVE TEST OF A BABCOCK & WILCOX BOILER; COMPARISON OF CLOSED ASH-PIT AND CLOSED FIRE-ROOM SYSTEMS OF FORCED DRAFT,

By Lieutenant Commander B. C. Bryan, U. S. Navy, Member;

with

NOTES ON WATER-TUBE BOILERS,

By Lieutenant Commander B. C. Bryan, U. S. Navy, and Lieutenant A. M. Procter, U. S. Navy.

The following tests of one of the Babcock & Wilcox boilers for the U. S. S. *Nebraska* were made at the works of the company at Bayonne, New Jersey, in December, 1903, by a Board consisting of Lieutenant Commanders B. C. Bryan and E. Theiss and Lieutenant C. P. Eaton, U. S. Navy:

DESCRIPTION OF BOILER "B," U. S. S. *NEBRASKA*.
TESTED DECEMBER 15-22, 1903.

The boiler is of the Babcock & Wilcox new marine type, composed of wrought steel, thirty sections wide. There are twenty-eight intermediate sections, each consisting of two headers, thirty-two 2-inch tubes and one 4-inch tube; and two side sections, each consisting of two headers, twenty-five 2-inch tubes and one 4-inch tube. On account of the width of the boiler there are three lower water sides, each consisting of two upright boxes, four 6-inch square boxes and one 4-inch tube. Two of these are at the sides and the other is near the middle of the width. The grate is divided by this middle lower water part into two sections: one 8 feet 3¼ inches wide, and the other 7 feet 8¼ inches wide. For experimental purposes, this boiler has a double front with a 3-inch air space. The air from this space passes from it through slots or slits in the door jambs to the furnaces over the grates. None of

the boilers in the Service have been fitted with this double front as yet, the intention being first to carry on a series of tests and experiments to determine its value.

BOILER DATA.

Steam drum, diameter inside, inches	42
length of shell, feet and inches	18– 3⅛
Tubes, 2 inches by 8 feet, *No. 8 B.W.G	946
4 inches by 8 feet, *No. 6 B.W.G	30
circulating, 4 inches by 6 feet, *No. 6 B.W.G	30
Grate surface, length 7 feet, width 8 feet 3½ inches and 7 feet 8½ inches, square feet	111.72
Heating surface, square feet	4,682
Ratio H. S. to G. S	41.9
Water-heating surface, per cent	100
Grate bars, kind	Fixed.
width of air spaces, inch	½
per cent. of air space	43
sections, 4 single bars in each	96
total, single bars	384
Smoke pipe, diameter 4 feet 6 inches, area, square feet	15.904
height above grate, feet	59
ratio area to G. S	1:7.02
Weight of boiler and fittings, except uptakes and smoke pipe, and without water	*lbs.* 97,133
Weight water 1st gauge cock, 6 inches below hor. center line	16,913
2d gauge cock, in horizontal center line	19,532
3d gauge cock, 6 inches above horizontal center line	21,974
boiler full	25,584

The normal steaming level is with water at 2d gauge cock.

Temperature of water when above weights were taken, 62 degrees F.

Total weight per sq. ft. grate surface (water at steaming level)	1,044
heating surface	24.9

Feed water: city water heated by live steam jet. Steam coil in feed tank also.

Feed pump: Worthington duplex, outside packed, plunger type; cylinders, steam end, 10 inches by 14 inches, water end, 6 inches by 14 inches.

Other boiler appurtenances: steam jet in stack to produce draft.

* These lengths are between headers, and between headers and steam drum; the whole length of the tubes being 8 feet 2 inches and 6 feet 3½ inches respectively.

The boiler was erected in a sheet-iron structure built especially for the test. The arrangement of same is shown in Fig. 9. The arrangement of blower and ducts is shown in Fig. 10. The blower was of the Davidson Sirocco fan type, driven by belt from a 30-H.P. Diehl motor. The fan could be driven to 550 revolutions, but the fastest speed found necessary on tests was 405 revolutions. The ducts were so arranged that air could be taken from the outside through door C, or from the fire room through door B, and delivered to the ash pans through ducts at rear end of boiler or into fire room by dropping door A. (Fig. 10.)

The fan worked satisfactorily in every way, and no difficulty was found in regulating the draft as required. The pressure in ash pits, when running with same closed, was regulated by means of dampers, the pressure in ducts being carried slightly higher and opening of damper adjusted to give required pressure. The dampers were worked from front of boiler by means of levers, and had adjustable stops, so they could be set to give any desired amount of opening. Dampers were also fitted for regulating the air passing through the double front of the boiler, but it was not found necessary to use these on any test.

The steam pressure was controlled by a valve on top of boiler shed, worked by hand. During working hours the steam necessary for running the shop engines, etc., in the vicinity was taken from the boiler, and the surplus was sent into the air through mufflers, as shown on Fig. 9. A shed was built adjoining the boiler house to cover the feed pump, weighing tanks, and space for taking gas samples and readings of various draft-pressure gauges.

The members of the Board saw all coal and water weighed and took the readings for all data recorded.

Scales, Instruments, Etc.—All scales used were of standard make and were tested by the Board with standard weights. All thermometer gauges, etc., were furnished by the company, and were of standard make and had been carefully tested and calibrated. The pyrometer used in base of smoke pipe was of the nitrogen-filled thermometer type, extending 22 inches into the gases and reading to 1,000 degrees Fahrenheit.

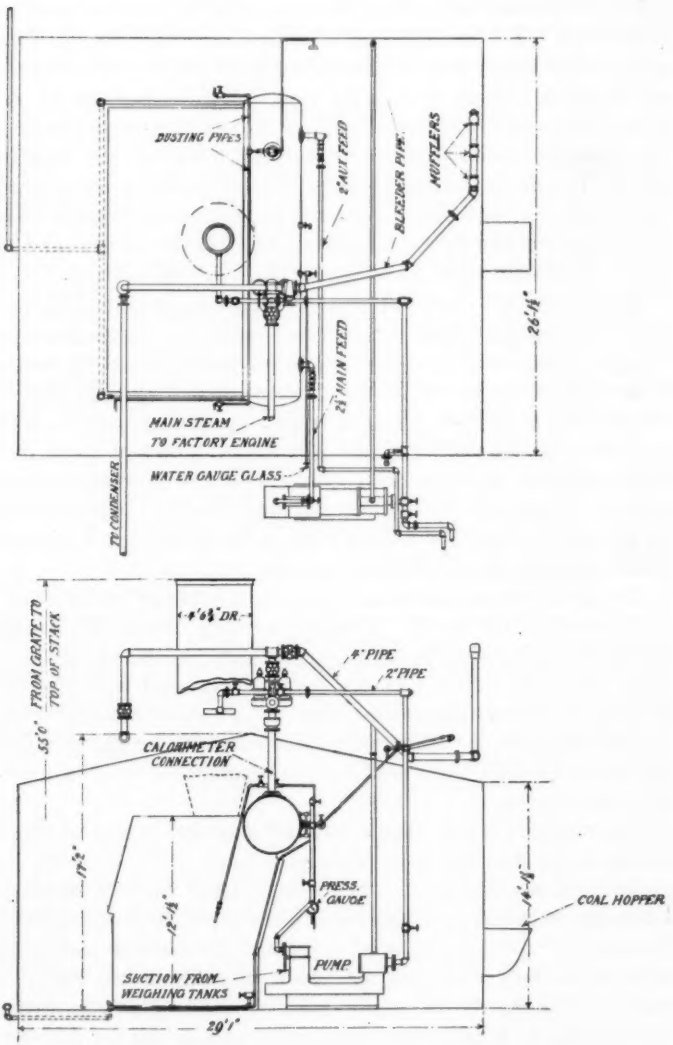


Fig. 9.—(*a*) PLAN, (*b*) SIDE ELEVATION.

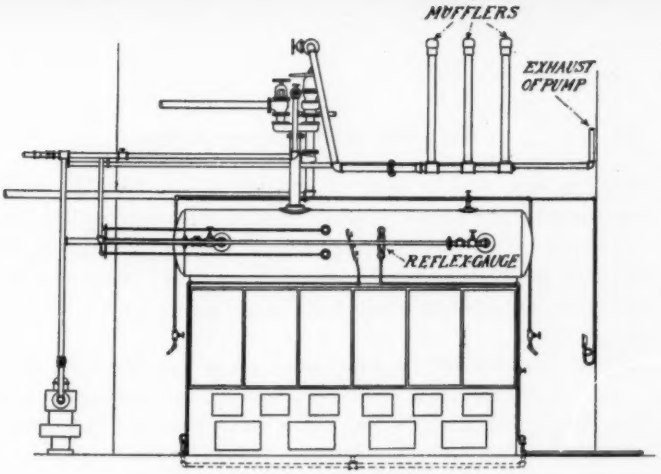


Fig. 9.—(*c*) FRONT ELEVATION.

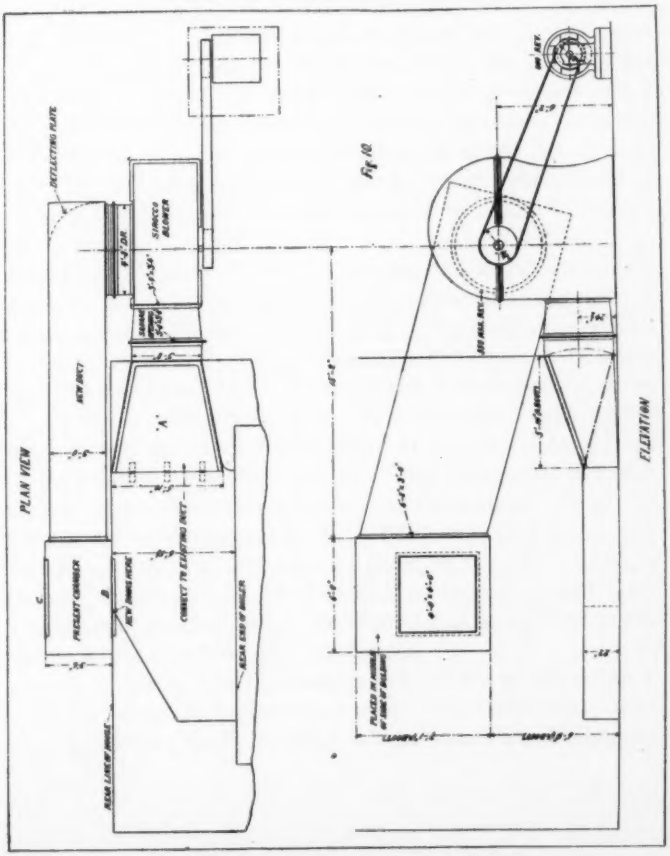


Fig. 10.—FORCED-DRAFT ARRANGEMENT.

Samples of gas were taken from base of pipe and analyses made by an Orsat apparatus. Samples were also drawn into cans and analyzed in the laboratory.

The pressure in furnace was taken from a pipe leading through the back casing at center of each grate and 32 inches above grate.

Ash-pit draft was taken from pipes at sides of ash pits, 9½ inches above bottom.

Method of Weighing Coal.—The coal was weighed in barrows, the weights of empty barrows being carefully marked and checked at intervals. Barrows were loaded with an even weight of 200 pounds of coal each, and carefully balanced. With the closed ash-pit system, the coal was weighed outside the boiler house and wheeled in. With the closed fire-room system, the coal was passed from outside to fire room from a hopper provided with a sliding door worked by a lever. To prevent escape of air when this door was open the hopper was kept as nearly full as possible. The weighing was done in the fire room. At the end of each hour the floor was swept and the coal weighed back on all tests.

Method of Weighing Water.—Arrangements for weighing the water were made by having three elevated iron tanks, each on separate standard platform scales. The scales were tested before and during tests, and weights of empty tanks checked at intervals. The water was led from city main to each tank, a steam jet being led into the pipe from main to warm the water. After being weighed the water was drained as required into a large feed tank placed below other tanks. This latter tank was calibrated so that water could be checked at any time. From the feed tank the water was sent to the boiler by the feed pump. All parts of tanks, piping, etc., were in plain sight. At the end of each hour the actual amount of water was checked up and water in upper tanks weighed back. A heating coil was placed in the lower tank, but was used only on test VI.

Quality of Steam.—For observing the quality of the steam a Barrus throttling calorimeter was used. The steam was taken from the vertical pipe from which all the steam was discharged

from boiler at a point 12 inches above top of drum. The collecting nozzle was of standard pattern. After the tests the calorimeter was calibrated by taking readings with pressure going up and down and no steam leaving boilers except through the calorimeter. From these standard readings the amount of moisture was calculated by the following formula:

$$Q = \frac{48\,(T - t)}{L} \times 100,$$

in which Q = percentage of moisture, T = calibration reading of lower thermometer, t = test reading of lower thermometer, L = latent heat of steam at boiler pressure.

Moisture in Coal.—Samples of coal weighing about 40 pounds were set aside to dry, the moisture as determined by this method being about 3½ per cent. Average samples were taken each day, from which the moisture was determined in the laboratory; these results were found to be less than by the other method, and were used by the Board in working up data. Between tests No. 4 and No. 5 there was a fall of snow, and on tests No. 5 and No. 6 the weather was damp and warmer.

Depth of Fires on Grates.—The depth of fires was judged by a member of the Board at the start and at the end of every hour, allowance being made for the probable amount of ash. On test No. 1 the last hour was thrown out, as it was considered that no adjustment of conditions could be made and the fires had been judged at the end of the preceding hour to be about the same as at start. On test No. 2 the fires were judged about ¾ inch lower in coal than at start, and 314 pounds were added as a correction, this being the amount to cover entire grate ¾ inch in depth at a weight of 45 pounds per cubic foot weight of burning coal.

THE TESTS.

Six tests in all were made, the first three using the closed ash-pit system of draft with draft pressures of ½, 1 and 1½ inches of water; the last three using the closed fire-room system, with approximately the same air pressures.

The coal used was hand-picked Pocahontas of good quality.

It burned freely, leaving only about 5 per cent. of ash, this being calculated by noting the total quantity of coal from time fires were started and total amount of ash after boiler was cleaned and tubes swept. It was found after each test that when furnace cooled off, a thin sheet of hard cinder was left on the grate bars, which was removed with difficulty. All coal used came from the same order, that used on Tests I, II and III came directly from the car. On Test IV it was noted at once that there was a difference, as the coal used on this test was very friable, and a light blow of the maul would reduce it to fine slack. On Tests V and VI, the coal was more like that used on Tests I, II and III, but had been exposed for a short time in the open air and came in smaller lumps with more slack.

During all tests, and especially during those under closed ash pits, the casing was examined from time to time, and at no time was it so hot that the hand could not be kept on the side or back. It was also found perfectly tight, the doors being well fitted and practically sealed when closed.

The firing was done by two men on all tests except No. III, when an extra man was put on. On Tests I, II, IV and V, two doors on one furnace and one on the other were fired or leveled at each operation, so that two doors were open one-half the time of working and one door open one-half the time. On Test III, three doors were opened together. On test VI one door was opened at a time.

The depth of fire was regulated, as near as possible, by the tests of the products of combustion and by the pressure in furnace, firing heavier or lighter, according to results shown.

It should be noted that the boiler was baffled to obtain certain results, it being calculated to burn a little over thirty pounds of coal per square foot of grate at one inch fire-room pressure. By decreasing the amount of baffling, more coal could have been burned, with probably but a slight reduction of efficiency.

A draft of one-half inch at base of smoke pipe was maintained throughout every test by means of a steam jet in the pipe, this being considered about the draft that could be expected with the height of pipe proposed for the vessel. This amount was care-

fully adjusted before each test, and remained practically constant without regulation of the jet throughout the test.

It was found, with even the lowest draft pressure used, that it was not safe to work the fires, when under ash-pit draft, without closing off the draft from both furnaces. At one-half inch pressure the fires were occasionally worked without closing the draft, but at such times a cloud of sparks would come out of the open door at intervals and endanger the fireman. At higher draft pressures it was not practicable even to open the doors without shutting off the draft, as flame, smoke and sparks were blown entirely across the fire room when this was tried.

A chart of firing is appended, on which is carefully noted the time draft was shut off or doors open on each test. From this it will be seen that the draft was entirely closed on Test I, 23.4 per cent.; on Test II, 24.6 per cent., and on Test III, 28.4 per cent. of the whole time of test.

Every effort was made to reduce this time and to fire in the way most favorable to the system of draft used. An extra fireman was put on on Test III, so that three doors could be fired or worked at once, and extra helpers were detailed to close and open draft.

With the closed ash-pit system, heavy coaling at long intervals was tried in order to reduce the time draft was shut off. With the lighter and more frequent firing, used with the closed fire-room system, the time the doors were open was from 35.6 to 39 per cent. of the whole time. Firing in the latter way with the closed ash-pit system would have caused the draft to have been shut off at least 40 per cent. of the time.

It is evident from this fact that the closed ash-pit system should not be used when a high rate of combustion is aimed at in a boiler of this type under Service conditions, by which is meant, a boiler having a grate large enough to require firing from several doors, with proper baffling for economy, the products passing directly to the same tube space, and the use of a powerful steam jet prohibited.

The boiler was carefully examined after the last test and found to be in good condition in all respects. The brickwork and

baffling were intact. A straightedge was laid along the lower tubes and no warping discovered. The casing was intact. An examination of the interior of the tubes showed no pitting nor injury. A small amount of mud mixed with what seemed to be patches of mill scale was found occasionally on the inside of tubes.

No difficulty was experienced in firing this depth (7 feet) of grate, and only 16 grate bars have had to be replaced since this boiler has been in use.

TEST No. 1, CLOSED ASH PIT,

.....	A. M.			
	10·00	10·30	11·00	11·30
Steam pressure, gauge, pounds	270	260	265	272
Water in gauge glass, inches	6½	1	6	7
Calorimeter, T_1, upper thermometer	...	...	408	...
T_2, lower thermometer	...	...	316	...
Q, water in steam, per cent	...	...	.146	...
Gauge pressure at reading, inches	...	...	275	...
Temperature of feed water, degrees, F.	82	91	100	106
outside air, degrees, F.	30	30	30	30
fire room, degrees, F	50	50	50	50
gases at base of stack, degrees, F.	....	665	660	650
Draft pressure, inches water, ash pit, right	.45	.75	.5	.5
left	.45	.75	.5	.5
furnace	.17	.17	.18	0
base of stack	—.5	—.5	—.5	—.5
Flue gases, CO_2	....	....	15.8	....
O	....	....	1.8	....
CO	....	....	1.2	....
Coal per hour, pounds	...	...	3637	...
total, pounds	...	...	...	...
Feed water per hour, pounds	...	...	29440	...
total, pounds	...	...	...	...

Weather, clear.
Barometer, 30.18.
Draft shut off both furnaces when coaling or leveling. Tried to work fires without shutting off draft, and found it possible, but dangerous.
Smoke, light, with puffs when firing.

TEST NO. 2, CLOSED ASH PIT,

.....	A. M.					
	9·05	9·35	10·05	10·35	11·05	11·35
Steam pressure, gauge, pounds	280	277	275	276	274	272
Water in gauge glass, inches	4½	Full	4½	6	5	3
Calorimeter, T_1, upper thermometer	...	Broken.	...	...	...	408
T_2, lower thermometer	...		...	...	....	317
Q, water in steam, per cent	...	...	...	...	...	.088
Gauge pressure at reading, inches	...	...	...	...	...	276
Temperature of feed water, degrees, F.	110	110	112	110	110	110
outside air, degrees, F.	22	24	26	28	28	28
fire room, degrees, F.	27	30	32	36	34	45
gases at base of stack, degrees, F.	625	685	700	720	630	675
Draft pressure, inches water, ash pit, right	.8	.6	.9	.9	.8	.8
left	.75	.80	.70	.90	1.00	.80
furnace	.37	.37	.37	.53	.25	.30
base of stack	—.5	—.5	—.5	—.5	—.5	—.5
Flue gases, CO_2	...	...	12.0	10.6	13.8	11.0
O	...	...	7.0	9.0	5.2	9.4
CO	...	...	0	0	0	...
Coal per hour, pounds	...	...	3007	...	2881	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	26309	...	26425	...
total, pounds	...	...	...	...	...	...

*314 Correction added for low fires at end of test.

Weather, clear.
Barometer, 29.24.
Found coaling or leveling impossible with draft on either furnace. Trying to spread coal or work fires as little as possible.
Blower running steadily at 250 revolutions, with 1.55 inches pressure in

½ INCH DRAFT.

	P. M.										Aver-age.
12·00	12·30	1·00	1·30	2·00	2·30	3·00	3·30	4·00	4·30	5·00	
275	275	280	280	275	270	276	275	280	270	275	271
4	3	1	3	1½	1½	5	7	8	7	3	...
408	...	408	...	408	...	408	...	407	...	409	....
319	...	319	...	317	...	319	...	318	...	318	....
0	...	0	...	.117	...	.059	...	.059	....	.059	.062
276	....	274	...	276	...	276	...	276	....	280	....
100	100	101	104	106	104	104	108	106	106	104	101.5
31	32	31	30	30	30	30	30	28	27	27	29.7
50	52	48	50	47	46	46	45	42	42	59	47.9
710	665	670	700	675	710	680	665	640	675	660	673
·5	·5	·45	·5	·5	·5	.6	·5	·55	·5	·5	·519
·5	·5	·45	·5	·45	·5	.6	·5	·55	·5	·5	
—.05	0	.10	.05	.07	.09	.09	.18	.15	.15	.08	.095
—·5	—·5	—·5	—·5	—·5	—·5	—·5	—·5	—·5	—·5	—·5	—·5
11.6	....	....	13.0	11.0	....	12.8	....	12.0	....	....	12.7
3.0	....	....	4.6	8.8	....	6.0	....	7.4	....	....	5.27
2.8	....	...	.4	□	...	.2	...	.3	...	...	.8
3400	...	2523	...	2682	...	3000	...	2355	...	2772	...
...	...	...	...	...	...	...	...	...	...	...	20369
25269	...	26427	...	25975	...	24697	...	23663	...	25791	...
...	...	...	...	...	...	...	...	...	...	...	181262

At 5·54 blew out fuse in electric connections; blower stopped, lights went out. Fires lower at end than at start. Fires at 5.00 P. M. judged same as at start. Last hour, from 5.00 to 6.00, thrown out.

Coal, hand-picked Pocahontas, direct from car in large lumps, broken as fired.

1 INCH DRAFT.

	P. M.										Aver-age.
12·05	12·35	1·05	1·35	2·05	2·35	3·05	3·35	4·05	4·35	5·05	
280	286	276	271	270	270	275	274	278	275	280	273.6
Full	Full	2	3½	6	3½	4½	4½	Full	2½	6	...
409	...	408	...	407	...	408	...	...	407	...	...
319	....	318	....	318	....	317	....	....	318	....	....
0	....	.029	...	0	....	.088	...	...	.059	...	.044
276	...	278	...	270	...	277	...	...	270	...	...
108	110	108	110	110	108	104	106	102	106	106	108.2
29	28	30	30	30	28	28	28	28	28	28	27.7
42	48	36	38	38	38	48	50	38	36	38	38.5
650	690	685	670	690	665	655	675	665	690	675	673.2
1.0	1.0	1.0	1.1	1.0	.8	1.0	1.15	1.1	1.2	1.2	.966
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	...	1.2	1.2	
.40	.43	.60	.54	.50	.56	.53	.58	.44	.44	.42	.449
—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5
...	...	...	12.6	11.4	...	...	...	...	...	...	11.9
...	...	...	6.6	7.8	...	...	...	...	...	...	7.5
...	...	0	0	...	...	...	...	...	...	...	0
2886	...	3267	...	3148	...	2639	...	2894	1523	1153*	...
...	...	...	...	...	...	...	...	...	...	...	23712
26503	...	31096	...	26254	...	25346	...	22134	18779	13167	...
...	...	...	...	...	...	...	...	...	...	...	216013

duct, until 3·20, when increased revolutions of blower to 300, with 1.82 inches pressure in duct. Draft in ash pits regulated by dampers.

Coal, hand-picked Pocahontas from pile near shed, finer than in Test No. 1, and containing more slack.

Fires judged ¼ inch low at end of test.

Smoke, very light to none, with puffs when firing.

TEST No. 8, CLOSED ASH PIT,

.....	A. M.					
	9·10	9·40	10·10	10·40	11·10	11·40
Steam pressure, gauge, pounds	255	273	266	276	274	272
Water in gauge glass, inches	3	1½	3	4	6	3½
Calorimeter, T_1, upper thermometer	...	...	407	...	408	...
T_2, lower thermometer	...	...	319	...	319	...
Q, water in steam, per cent	...	...	0	...	0	...
Gauge pressure at reading	...	...	271	...	276	...
Temperature of feed water, degrees, F.	88	101	114	107	108	116
outside air, degrees, F.	28	30	32	32	34	36
fire room, degrees, F.	42	44	50	48	50	52
gases at base of stack, degrees, F.	...	720	735	730	685	675
Draft pressure, inches water, ash pit, right	1.30	1.25	1.35	1.35	1.30	1.40
left	1.20	1.25	1.30	1.30	1.35	1.50
furnace	.73	.61	.79	.83	.84	1.00
base of stack	—.5	—.6	—.6	—.5	—.5	—.5
Flue gases, CO_2	...	13.6	12.0	...	...	...
O	...	5.7	7.4	...	...	...
CO	...	0	0	...	...	...
Coal per hour, pounds	...	...	3715	...	3706	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	32617	...	32765	...
total, pounds	...	...	...	...	...	...

Weather, clear. Barometer, 30.15.

Trying different thickness of fires, from 6 to 12 inches. Put in extra fireman at 2·35 to coal or level three furnaces at once; in order to reduce time, draft was shut off.

TEST No. 4, CLOSED FIRE ROOM

.....	A. M.					
	9·15	9·45	10·15	10·45	11·15	11·45
Steam pressure, gauge, pounds	287	278	279	270	272	270
Water in gauge glass, inches	4	3½	4	2	4	2
Calorimeter, T_1, upper thermometer	...	...	407	...	408	...
T_2, lower thermometer	...	...	317	...	318	...
Q, water in steam, per cent	...	...	.176	...	.030	...
Gauge pressure at reading, inches	...	...	272	...	278	...
Temperature of feed water, degrees, F.	92	102	108	106	108	106
outside air, degrees, F.	32	32	32	33	34	34
fire room, degrees, F	67	58	58	50	62	63
gases at base of stack, degrees, F.	...	625	645	655	655	670
Draft pressure, inches water, ash pit, right	...	.6	.6	.6	.55	.55
left	.5	.5	.5	.5	.5	.55
fire room	.6	.65	.6	.6	.65	.6
furnace	.3	.27	.25	.18	.15	.17½
base of stack	—.3	—.5	—.5	—.5	—.5	—.5
Flue gases, CO_2	...	...	12.6	13.6	...	...
O	...	...	6.2	4.8	...	...
CO	...	...	.2	.2	...	...
Coal per hour, pounds	...	...	3863	...	3258	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	32045	...	31313	...
total, pounds	...	...	...	...	...	...

Weather, clear. Barometer, 30.46.

Coal from same order, but different from that used on first three tests; much softer, and crumbled into fine dust with light tap of maul.

1½ INCHES DRAFT.

P. M.											Average.
12·10	12·40	1·10	1·40	2·10	2·40	3·10	3·40	4·10	4·40	5·10	
255	282	277	284	275	284	267	275	285	280	295	275
4½	6	3	5	½	4	4	4	4	3½	0	...
...	407	...	...	407	...	408	...	408	...	...	...
...	319	...	...	318	...	319	...	319	...	...	...
...	0	...	...	.059	...	0	...	0	...	...	.01
...	285	...	...	269	...	276	...	276	...	...	...
118	110	110	114	118	116	106	114	114	114	110	110.5
36	36	38	38	38	38	38	37	36	36	34	35.1
50	52	55	54	52	58	56	54	54	52	52	51.5
715	695	680	690	710	720	740	760	750	725	730	716
1.50	1.70	1.50	1.25	1.50	1.50	1.50	1.45	1.60	1.60	1.50	1.466
1.60	1.70	1.50	1.50	1.70	1.55	1.50	1.50	1.50	1.70	1.65	
1.00	1.00	.75	.58	.66	.59	.44	.51	.64	.68	.65	.723
—.45	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.51
...	...	...	11.2	...	12.0	...	...	...	14.4	10.8	12.3
...	...	...	8.5	...	7.6	...	...	...	5.0	8.6	7.1
...	...	...	0	...	0	...	...	...	0	0	0
3643	...	3975	...	3598	...	3823	...	3983	...	3701	...
...	...	...	...	...	...	...	...	...	...	...	30144
33523	...	33937	...	33101	...	33140	...	37076	...	36904	...
...	...	...	...	...	...	...	...	...	...	...	273063

Fires judged at 5·10 P. M.; same as at start.
Coal same as on test No. 2, containing about 5 per cent. slack.
Smoke, light to none, except puffs when firing.

½ INCH DRAFT.

P. M.											Average.
12·15	12·45	1·15	1·45	2·15	2·45	3·15	3·45	4·15	4·45	5·15	
272	281	263	270	281	282	279	276	274	272	277	273.3
2	6	4	3½	Full.	4	4	4	4	4	4	...
408	...	408	...	408	...	409	...	408	...	...	...
319	...	319	...	318	...	320	...	319	...	...	...
0	...	0	...	.030	...	0	...	0	...	...	.033
277	...	277	...	278	...	281	...	274	...	...	...
106	96	100	104	104	102	106	106	106	108	108	104
34	36	36	36	34	32	32	30	30	28	28	32.5
64	62	60	60	60	56	56	55	54	54	54	59
660	650	695	700	705	700	720	690	700	705	705	680
.5	.6	.6	.55	.6	.6	.55	.45	.4	.35	.35	.51
.5	.55	.6	.55	.55	.6	.55	.4	.4	.35	.35	
.6	.65	.65	.65	.65	.65	.6	.45	.4	.4	.4	.576
.11	.15	.17	.12	.18	.19½	.13	—.07	—.04	—.11½	—.1	.14
—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5
...	...	13.8	...	13.9	...	...	...	13.0	12.0	...	13.2
...	...	4.4	...	6.1	...	...	...	7.0	7.6	...	6.0
...	...	.2	...	.4	...	...	...	.3	.2	...	.25
3679	...	3297	...	3578	...	3402	...	3328	...	2970	...
...	...	...	...	...	...	...	...	...	...	...	27375
30567	...	30411	...	28762	...	30283	...	28067	...	27552	...
...	...	...	...	...	...	...	...	...	...	...	239000

Smoke, medium all the time, with puffs when firing.
Fires at end judged same as at start.

TEST No. 5, CLOSED FIRE ROOM,

.....	A. M.				
	9·00	9·30	10·00	10·30	11·00
Steam pressure, gauge, pounds	279	277	274	278	279
Water in gauge glass, inches	3	4	3	4	2½
Calorimeter, T_1, upper thermometer	...	...	405	...	408
T_2, lower thermometer	...	...	317	...	318
Q, water in steam, per cent	...	...	.176	...	.059
Gauge pressure at reading, inches	...	...	267	...	273
Temperature of feed water, degrees, F	118	104	98	96	96
outside air, degrees, F	40	40	42	42	44
fire room, degrees, F	58	62	66	68	70
gases at base of stack, degrees, F	640	665	660	685	680
Draft pressure, inches water, ash pit, right	.75	.75	.75	.95	.95
left	.70	.75	.75	.95	.90
fire room	.85	.85	.85	1.05	1.05
furnace	.32	.43	.45½	.49½	.52½
base of stack	—.5	—.5	—.5	—.5	—.5
Flue gases, CO_2	...	...	...	...	12.8
O	...	...	...	...	6.2
CO	...	...	...	...	0
Coal per hour, pounds	...	...	4016	...	3596
total, pounds	...	...	...	...	...
Feed water, per hour, pounds	...	...	30563	...	31994
total, pounds	...	...	...	...	...

Weather, damp; snow fell since last test and coal was exposed to weather.
Barometer, 29.83.
Coal, same as Test No. 4, until about 12·30, when it began to come from a different car load more like that used on first three tests.

TEST No. 6, CLOSED FIRE ROOM,

.....
Steam pressure, gauge, pounds
Water in gauge glass, inches
Calorimeter, T_1, upper thermometer
T_2, lower thermometer
Q, water in steam, per cent
Gauge pressure at reading, inches
Temperature of feed water, degrees, F
outside air, degrees, F
fire room, degrees, F
gases at base of stack, degrees, F
Draft pressure, inches water, ash pit, right
left
fire room
furnace
base of stack
Flue gases, CO_2
O
CO
Coal per hour, pounds
total, pounds
Feed water per hour, pounds
total, pounds

*—69 Correction coal swept off floor.

Weather, damp.
Barometer, 29.82.
Coal used, a mixture of that used on tests Nos. 4 and 5.

1 INCH DRAFT.

		P. M.									Average.
11·30	12·00	12·30	1·00	1·30	2·00	2·30	3·00	3·30	4·00	4·30	
281	289	284	274	272	285	273	267	276	276	287	276
4½	5½	3½	3½	2	4	3½	1½	3½	5	5	...
...	409	...	408	...	408	...	408	...	405	...	...
...	318	...	317	...	318	...	319	...	318	...	...
...	.059	...	.088	...	.059	...	0	...	.030	...	.067
...	274	...	275	...	272	...	275	...	272	...	...
94	93	98	105	96	104	104	100	104	102	96	100.5
46	46	46	46	46	44	46	44	42	42	41	43.6
72	74	72	70	70	69	68	67	66	64	62	67.4
710	710	680	675	700	715	700	695	705	700	695	689
.90	.95	.90	.95	1.00	1.00	1.00	1.00	1.10	1.10	1.25	.955
.95	.95	.90	.95	1.00	1.00	1.00	1.00	1.10	1.10	1.25	
1.05	1.05	1.00	1.05	1.10	1.10	1.10	1.10	1.20	1.20	1.35	1.06
.43	.62	.52	.63½	.53	.61½	.62½	.55	.57½	.61	.61	.534
—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5
12.0	...	14.4	...	...	...	...	...	13.8	...	..	13.25
7.0	...	5.4	...	...	...	...	...	6.0	...	...	6.15
0	...	0	...	...	...	...	...	0	...	...	0
...	3385	...	3400	...	4000	...	3610	...	3750	1531	...
...	...	...	...	...	...	...	...	...	...	...	27288
...	32179	...	34834	...	32971	...	34412	...	31391	...	17080
...	...	...	...	...	...	...	...	...	...	...	245424

Smoke, heavy to medium all the time, with puffs when firing.
Ended test at 4·30 P. M. to leave enough coal for next test.
Fires judged same at end of test as at start.

1½ INCHES DRAFT.

A. M.					P. M.						Average.
10·00	10·30	11·00	11·30	12·00	12·30	1·00	1·30	2·00	2·30	3·00	
281	275	282	280	277	277	272	280	277	276	286	27.63
2½	3½	4½	3	3	7	½	2½	3	3	4	...
...	...	409	...	410	...	409	...	408	...	...	...
...	...	317	...	318	...	317	...	318	...	...	...
...	...	.117	...	.117	...	.117	...	.030	...	...	.095
...	...	285	...	289	...	287	...	278	...	...	...
104	112	112	118	118	119	118	116	118	118	118	115.5
44	45	42	43	45	44	44	46	46	43	43	44
66	64	62	62	66	66	64	64	64	62	62	64
675	660	675	680	700	685	680	715	700	725	725	693
1.2	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.5
1.2	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.5	
1.30	1.50	1.70	1.65	1.65	1.70	1.75	1.75	1.75	1.80	1.70	1.66
.70	.92½	1.08½	.85	.95½	.92	.91	1.08½	.85	1.03	.98	.93
—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5	—.5
...	...	8.2	10.0	...	10.0	11.6	...	...	...	...	9.95
...	...	11.4	9.2	...	9.8	7.2	...	...	...	...	9.40
...	...	0	0	...	0	0	...	...	...	...	0
...	...	4627	...	4248	...	4249	...	4358	...	4535*	...
...	...	...	...	...	...	...	...	...	...	...	21948
...	...	36183	...	40581	...	38740	...	39498	...	41346	...
...	...	...	...	...	...	...	...	...	...	...	196348

Smoke, medium when firing, but quickly disappearing to none between firings.
Stopped test at end of 5th hour as coal of quality being used was nearly exhausted.
Fires judged same at end of test as at start.

FIRING CHART.

C = coal. L = level. T = total. A = average.

Test No. 1.

CLOSED ASH PIT—$\frac{1}{4}$-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L
h. m.												
10 09	c				c				c			
11				1				1				1
13												
15			c				c				c	
17		1				1				1		
19												
21	c				c				c			
23				1				1			1	1
25												
27			c				c				c	
29		1				1				1		
31	c				c				c			
33				1				1				1
35												
37												
39			c				c				c	
41		1				1				1		
43												
45	c				c				c			
47				1				1				1
49			c				c				c	
51												
53		1				1				1		
55	c				c				c			
57				1				1				1
2 28				1				1				1
30			c				c				c	
32												
34		1				1				1		
36												
38	c				c				c			
40				1				1				1
42			c				c				c	
44												
46		1				1				1		
48	c				c				c			
50												
52				1				1				1
54			c				c				c	
56		1				1				1		
58												
3 00	c				c				c			
02				1				1				1
04												
06			c				c				c	
08		1				1				1		
10	c				c				c			
12												
14				1				1				1
16												
18			c				c				c	
20		1				1				1		

Average time between two consecutive coalings of same door = 12 m. 51 s. = 771 sec.
Average coal per hour = 2910. Average coal fed each door at each coaling = $\frac{2910}{3600} \times \frac{771}{3600}$ = 103.8 lbs.
Average coal fired at each coaling (3 doors), 311.4 lbs.

Opening two doors on one furnace and then one on other at each time.
Doors open 20 sec. firing and 18 sec. leveling.
Each time—Firing 40 sec., leveling 36 sec.
Total 10'09 to 10'57 = 48 min.
Firing.....9 × 40 = 360 sec.
Leveling. .....9 × 36 = 324 sec.
2'28 to 3'20 = 52 min.
Firing .....9 × 40 = 360 sec.
Leveling.....10 × 36 = 360 sec.

1404 sec.

Total—100 min. or 6000 sec.
Draft off $\frac{1404}{6000}$ × 100 = 23.4 per cent.

Test No. 4.

CLOSED STOKEHOLD—$\frac{1}{4}$-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L	Time door open. T	A
h. m. s.														
10'54'45			c				c				c		40	20
55'30		1				1				1			42	21
56														
58'25	c				c				c				45	22½
11'00'10				1				1				1	40	20
01'30			c				c				c		42	21
02														
03'25		1				1				1			40	20
04														
05'30	c				c				c				39	19½
06														
07'12				1				1				1	28	14
08'38			c				c				c		32	16
10'10		1				1				1			39	19½
12'18	c				c				c				37	18½
14'45				1				1				1	36	18
15'32			c				c				c		38	19
16														
17'15		1				1				1			30	15
18														
19'20	c				c				c				48	24
20														
21				1				1				1	30	15
22'40			c				c				c		30	15
24'12		1				1				1			38	19
3'51'25			c				c				c		35	17½
52'40		1				1				1			40	20
53														
54'28	c				c				c				38	19
55														
56'25				1				1				1	30	15
57														
58			c				c				c		34	17
59'45		1				1				1			30	15
4'01'25	c				c				c				30	15
03'15				1				1				1	29	14½
04'40			c				c				c		30	15
05'45		1				1				1				
07'30	c				c				c				32	16
08'55				1				1				1	33	16½
09														
10'15			c				c				c		25	12½
11'45		1				1				1			29	14½
13'10	c				c				c				30	15
14'50				1				1				1	25	12½
15														
16'10			c				c				c		48	24
17'50		1				1				1			28	14
19'25	c				c				c				30	15
20'40				1				1				1	36	18
21'55			c				c				c		35	17½

10'54'45 to 11'24'40 = 29 min. 55 sec.
3 51'25 to 4'22'30 = 31 min. 55 sec.

61 min. 50 sec. or 3710 seconds.

Doors open 1321 sec. = $\frac{1321}{3710}$ × 100 = 35.6 per cent.
Average time between two consecutive coalings of same door = 6 min. 31 sec. = 391 sec.
Average coal per hour 3422 pounds.
Average coal fed each door at each coaling = $\frac{2422}{9} \times \frac{391}{3600}$ = 62.
Average coal fired at each coaling (3 doors) 186 lbs.

FIRING CHART.

C = coal. L = level. T = total. A = average.

Test No. 2.

CLOSED ASH PIT——1-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L	Time draft shut off.
h. m. s.													*sec.*
50 11·49·30	c				c				c				
11·51				1				1				1	32
53			c				c				c		63
55													
60													
12·01·00	c				c				c				60
5													
05·50				1				1				1	80
07·20			c				c				c		50
10													
12·00		1				1				1			55
15 14·20	c				c				c				55
...	...	...	...	...	...	...	...	...	...	...	...	...	...
2·17·40				1				1				1	50
18			c				c				c		
21·20		1				1				1			40
23													
24·40	c				c				c				55
26·55				1				1				1	40
28													
30·40			c				c				c		50
33													
34·55		1				1				1			40
38													
38·40	c				c				c				70
43 42·40				1				1				1	40
46·00			c				c				c		55
48													
49·30		1				1				1			42
52·00	c				c				c				60
53													
56·15				1				1				1	40
58													
3·00·50			c				c				c		55
3·03													

11·49·30 to 12·15·15 = 25 min. 45 sec.
2·17·40 to 3·01·45 = 44 min. 5 sec.

Total time, 69 min. 50 sec. = 4190 sec.
Draft off $\frac{1888}{4190} \times 100 = 24.6$ per cent. of time.
Average time between two consecutive coalings of same door = 13 min. 40 sec. = 820 sec.
Average coal per hour 2964 pounds.
Average coal fed each door at each coaling = $\frac{2258}{6} \times \frac{820}{2640} = 112.5$ pounds.
Average coal fired each coaling (3 doors) = 337.5 lbs.

Test No. 5.

CLOSED STOKEHOLD——1-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L	Time doors open. T	A
h. m. s.														
10·18·50			c				c				c		30	15
20														
20·5		1				1				1			25	12½
21·12	c				c				c				22	11
22·20				1				1				1	18	9
23·28			c				c				c		16	8
25														
25·10		1				1				1			20	10
25·50	c				c				c				20	10
27·00				1				1				1	30	15
28·00			c				c				c		30	15
29·05		1				1				1			26	13
30														
30·04	c				c				c				26	13
31·10				1				1				1	30	15
32·00			c				c				c		30	15
33·08		1				1				1			28	14
35 34·20	c				c				c				21	10½
35·25				1				1				1	25	12½
36·15			c				c				c		24	12
37·12		1				1				1			22	11
38·20	c				c				c				21	10½
39·20				1				1				1	18	9
40 40·28			c				c				c		18	9
41·23		1				1				1			27	13½
42·40	c				c				c				32	16
43 45				1				1				1	28	14
44·45			c				c				c		24	12
45 45·52		1				1				1			21	10½
46·45	c				c				c				23	11½
47·50				1				1				1	22	11
48·44			c				c				c		21	10½
49·40		1				1				1			21	10½
50														

10·18·50 to 10·50·01 = 31 min. 11 sec. = 1871 sec.
Doors open $\frac{719}{1871} \times 100 = 36.7$ per cent. of time.
Average time between two consecutive coalings of same door = 4 min. 20 sec. = 260 sec.
Average coal per hour 3638 pounds.
Average coal fed each door at each coaling = $\frac{2528}{6} \times \frac{260}{2640} = 43.8$ lbs.
Average coal fired at each coaling (3 doors) 131.4 lbs.

FIRING CHART.

C = coal. L = level. T = total. A = average.

Test No. 3.

CLOSED ASH PIT—1½-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L	Time draft shut off.
A. M.													
h. m. s.													*sec.*
10°29'40				1				1				1	40
32'20			c				c				c		45
35'20		1				1				1			40
38'55	c				c				c				40
40'40				1				1				1	30
42'35			c				c				c		45
45'00		1				1				1			42
47'15	c				c				c				55
50'15				1				1				1	30
52'05			c				c				c		40
54'35		1				1				1			37
56'50	c				c				c				40
11°00'10				1				1				1	32
01'30			c				c				c		38
04'00		1				1				1			35
06'15	c				c				c				57
09'50				1				1				1	35
12'18			c				c				c		57
14'33		1				1				1			37
17'00	c				c				c				42
19'50				1				1				1	28
22'03			c				c				c		37
24'55		1				1				1			47
29'45	c				c				c				46
31'40				1				1				1	30
P. M.													
2°20'40		1				1				1			40
22'40	c				c				c				55
25'18				1				1				1	40
27'15			c				c				c		40
29.10		1				1				1			45
31'15	c				c				c				45
34'20				1				1				1	38
36'10			c				c				c		35
38'10		1				1				1			30
40'40	c				c				c				27
42'08				1				1				1	24
44'25			c				c				c		30
46'20		1				1				1			35
49.54	c				c				c				26
50'50				1				1				1	25
52'40			c				c				c		25
55'10		1				1				1			32
56'50	c				c				c				28
58'55				1				1				1	30
3°01'25			c				c				c		32
03'50		1				1				1			30
05'35	c				c				c				35
07'30				1				1				1	30
09'40			c				c				c		30
11'55		1				1				1			25
13'25	c				c				c				30
15'40				1				1				1	28
18'10			c				c				c		28
20'20		1				1				1			26

Test No. 6.

CLOSED STOKEHOLD—1½-INCH DRAFT.

Time.	Door Numbers. 1 C	1 L	2 C	2 L	3 C	3 L	4 C	4 L	5 C	5 L	6 C	6 L	Time door open. T	A
A. M.														
h. m. s.														
11°22'15					1 3				1 2				1 1 42	14
23'20			c 3				c 2				c 1		55	18
24'20	c												18	18
27'30		1 2					1 1				1 3		42	14
29'18	c 2				c 1				c 3				50	17
31'00					1 3				1 2				1 1 55	18
32'47			c 3				c 2				c 1		50	17
*35'45		1 2					1 1				1 3		49	16
37'18	c 2				c 1				c 3					
39'06					1 3				1 2				1 1 50	17
40'44			c 3				c 2				c 1		51	17
42'40		1 2					1 1				1 3			
44'25	c 2				c 1				c 3				66	22
46'28					1 3				1 2				1 1 54	18
48'38			c 3				c 2				c 1		51	17
51'09		1 2					1 1				1 3		55	18
53 08	c 2				c 1				c 3				56	19

* Long interval to take gas sample.

11°22'15 to 11°54'04 = 31 min. 49 sec. = 1909 sec.

Doors open $\frac{744}{1909} \times 100 = 39$ per cent. of time.

Average time between consecutive coalings or levelings of same door = 8 min. 21 sec. = 501 sec.

Coal per hour 4390.

Average coal fed each door at each coaling = $\frac{4390}{6} \times \frac{501}{3600} = 101.8$ pounds.

Average coal fired each coaling (3 doors) = 305.4 lbs.

Remarks on Test 3.

10°29'40 to 11°32'10 = 1 hr. 2 min. 30 sec.
2°20'40 to 2°34'58 = 14 min. 18 sec.
Total = 1 hr. 16 min. 48 sec. = 4608 sec.

Draft off = $\frac{1328}{4608} \times 100 = 28.4$ per cent. of time.

At 2'35 extra fireman put on.

2'34'58 to 3'20'46 = 45 min. 48 sec. = 2748 sec.

Draft off = $\frac{644}{2748} \times 100 = 23.3$ per cent. of time.

Average time draft was off:

$$\left.\begin{array}{r} 5.42 \times 28.4 = 154 \\ 2.58 \times 23.3 = 60 \\ \hline 214 \end{array}\right\} 2\frac{14}{15} = 26.7$$

Average time between two consecutive coalings of the same door = 9 min. 11 sec.

Coal per hour = 3768.

Average coal fed each door at each coaling = $\frac{3768}{6} \times \frac{551}{3600} = 96.1$ pounds.

Average coal fired each coaling (3 doors) = 288.3 lbs.

Number of Test	1	2	3	4	5	6
1. Date of test	1903, Dec. 15.	1903, Dec. 16.	1903, Dec. 17.	1903, Dec. 18.	1903, Dec. 21.	1903, Dec. 22.
2. Duration of test, hours	*7	8	8	8	7½	5
3. Kind of fuel		Hand picked Pocahontas coal.			as coal.	
4. Kind of start.....Alternate	Alt.	Alt.	Alt.	Alt.	Alt.	Alt.
5. State of weather	Clear.	Clear.	Clear.	Clear.	Snow and rain	Clear.
Average Pressures.						
6. Barometer, inches	30.18	30.04	30.15	30.46	29.83	29.82
7. Steam pressure by gauge, pounds	271	273.6	272.2	273.3	275	276.3
8. Force of draft at base of pipe, ins. water	—.5	—.5	—.51	—.5	—.5	—.5
9. Force of draft in furnace, ins. of water	.095	.5	.723	.16	.534	.93
10. Force of draft in ash pit, ins. of water	.52	.97	1.466	.51	.955	1.5
Force of draft in fire room, ins. of water	...	...	...	.57	1.06	1.66
11. Revolutions of blower	...	...	...	...	...	320
Average Temperatures.						
12. External air, degrees F	29.7	27.7	34.5	32.5	43.6	44
13. Fire room, degrees F	47 9	38.5	51.5	59	67.4	64
17. Feed water, entering boiler, degrees F	101.5	108.2	110 5	104	100.5	115.5
19. Escaping gases from boiler, degrees F	673	650	716	680	688	693
Fuel.						
21. Kind of.....Pocohontas coal	...	...	...	...	...	...
23. Weight of coal as fired,* pounds	20,369	23,712	30,144	27,375	27,288	21,948
24. Moisture in coal, per cent	2.0	2.0	2.16	2.17	3.26	3.59
25. Weight of dry coal consumed, pounds	19,962	23,238	29,493	26,781	26,398	21,160
26. Weight of ash and refuse, pounds	820	1,215	1,363	1,261	1,268	1,011
27. Weight of combustible consumed, pounds	19,142	22,023	28,120	25,520	25,130	20,149
28. Per cent. of refuse in dry coal	4.11	5.23	4.62	4.71	4.78	4.78
Fuel per Hour.						
29. Coal consumed, pounds	2,910	2,964	3,768	3,422	3,638	4,390
30. Dry coal consumed, pounds	2,852	2,904	3,687	3,348	3,519	4,232
31. Combustible consumed, pounds	2,735	2,752	3,515	3,190	3,350	4,030
32. Coal consumed per sq. ft. G. S., pounds	26.05	26.53	33.73	30.63	32.56	39.29
33. Dry coal consumed per sq. ft. G. S., lbs.	25.52	25.99	33.00	29.97	31.50	37.88
34. Combustible consumed per sq. ft. G.S., lbs.	24.48	24.64	31.46	28.56	29.99	36.09
35. Coal per sq. ft. H. S., pounds	.621	.633	.805	.731	.777	.938
36. Dry coal per sq. ft. H. S., pounds	.609	.620	.787	.715	.752	.904
37. Combustible per sq. ft. H. S., pounds	.584	.588	.751	.681	.715	.861
Quality of Steam.						
38. Per cent. of moisture in steam	.06	.04	.01	.033	.07	.095
40. Quality of steam (dry steam = 100)	.9994	.9996	.9999	.9997	.9993	.999
Water.						
41. Total weight of water fed to boiler,† lbs.	181,262	216,013	273,063	239,000	245,424	196,348
42. Water actually evaporated, corrected for quality of steam (40 by 41), pounds	181,153	215,927	273,036	238,911	245,252	196,161
43. Factor of evaporation	1.1795	1.1723	1.1696	1.1763	1.181	1.164
44. Equivalent water evaporated into dry steam from and at 212° (42 by 43), lbs.	213,670	253,131	319,343	283,031	289,643	228,531
Water per Hour.						
45. Water evaporated, corrected for quality of steam, pounds	25,879	26,991	34,133	29,865	32,700	39,232
46. Equivalent evaporation from and at 212°	30,524	31,641	39,918	35,125	38,619	45,716
47. Equivalent evaporation from and at 212° per sq. ft. G. S., pounds	273.2	283.2	357.3	314.4	346.1	409.2
48. Same per sq ft. H. S., pounds	6.52	6.76	8.53	7.85	8.26	9.77
Economic Results.						
49. Water apparently evaporated under actual conditions per pound of coal as fired (41 ÷ 23), pounds	8.90	9.11	9.06	8.73	8.99	8.95
50. Apparent equivalent evaporation from and at 212° per pound of coal (including moisture) 44 ÷ 23, pounds	10.48	10.67	10.62	10.34	10.62	10.41
51. Equivalent evaporation from and at 212° per pound of dry coal (44 ÷ 25), pounds	10.70	10.89	10.83	10.57	10.97	10.80
52. Equivalent evaporation from and at 212° per pound of combustible (44 ÷ 27), lbs.	11.16	11.49	11.36	11.09	11.53	11.34
Remarks and Observations.						
55. Principal data taken every.....minutes	30	30	30	30	30	30
56. Percentage of smoke as observed	(a)	(b)	(c)	(d)	(e)	(f)
58. Kind of firing (spreading, alternate or coking),	Alternate	Alt.	Alt.	Alt.	Alt.	Alt.
59. Average thickness of fires, inches	6	7	8	6	6½	6
60. Average intervals between firings for each furnace during time fires were in normal condition, minutes and seconds	11'3	13'4	9'30	6'31	4'16	8'9
61. Average interval between times of breaking up, minutes and seconds	11'3	13'4	9'30	6'31	4'16	8'9
62. Efficiency of firemen; expert, average or poor	Expert	Expert	Expert	Expert	Expert	Expert

(*a*). Light with puffs when firing.
(*b*). Light puffs when firing to o between.
(*c*). Puffs when working fires to very light between.
(*d*). Medium at all times. Heavy puffs when firing.
(*e*). Medium to heavy. Puffs when firing.
(*f*). Heavy puffs when firing to o between.

*Including equivalent of wood used in lighting fires.
†Corrected for inequality of water level and steam pressure at beginning and end of test.

NOTES ON WATER-TUBE BOILERS.

Accurate and complete data upon the actual performance of water-tube boilers in actual service are hard to obtain. Performances of propelling machinery, as a whole, depend upon so many different conditions that they are, as a rule, of little value. It is difficult to separate the performance of the boiler from that of the engine, but perhaps the greatest difficulty in estimating the performance of the whole is the doubt as to the accuracy of figures of the amount of coal burned.

All of the earlier types of water-tube boilers were deficient in economy. This was due sometimes to insufficient furnace space, but more often to lack of provision for distribution of the heated gases over the heating surface.

It is not alone sufficient that a boiler be given a certain ratio of heating surface. Provision should be made for bringing the heated gases in actual contact with the heating surface and keeping them there long enough for them to part with their heat.

Almost all of the earlier boilers were deficient in this respect, notably the Yarrow and the Thornycroft *Speedy* type. Here the gases were shunted directly up the smokestack. Large powers have been obtained undoubtedly by the high forcing to which they easily lend themselves, and, because of the very slight resistance they offer to the passage of air, very large amounts of coal can be burned on low air pressures, but these large powers are probably obtained at a very extravagant expenditure of fuel.

The air pressure alone gives no clue to the extent to which a boiler is being forced, and here is recorded an objection to the practice of limiting the air pressure to any fixed amount on trial trips.

The amount of coal which can be burned depends upon the power of the blower and upon the resistance of the boilers, and the air pressure may be raised very largely by varying the thickness of the fire.

The trials of the nine Japanese 31-knot destroyers were run with about one inch of air pressure, some of them with less, and yet these boilers were certainly forced very hard.

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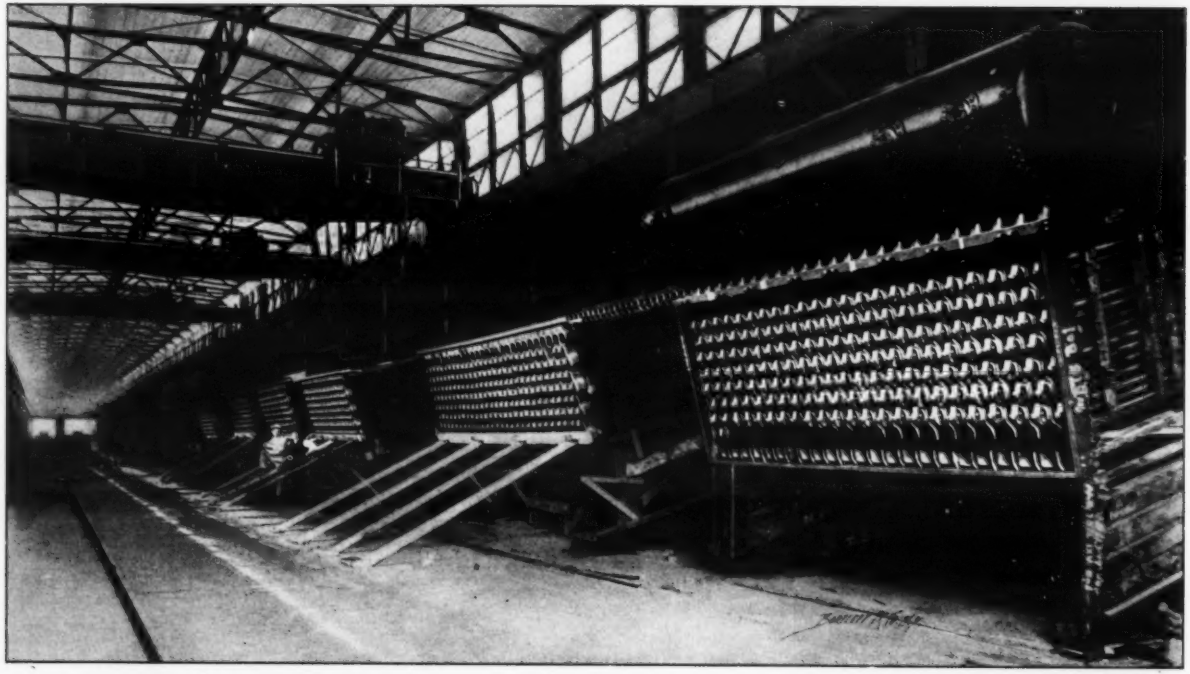


BABCOCK & WILCOX BOILERS FOR U. S. BATTLESHIP "NEBRASKA." ERECTED IN SHOP.

Boiler tests alone can give an accurate comparison of various types, and it is unfortunate that so few complete and reliable tests are available for comparison.

Single tests of different types of boilers are of little value unless made at the same rate of combustion, for it is a well-known fact that the efficiency varies with the rate of combustion, and this variation may follow a very different law for different boilers.

In the accompanying chart (Plate I) have been plotted the records of several series of boiler tests—that is, tests at varying rates—and it is believed that they represent all that are available. The boilers represented are:

1. The B. & W., *Nebraska;*
2. The B. & W., *Cincinnati;*
3. The B. & W., *Alert.*

These represent successive types of this boiler, showing the results of the effort to increase the efficiency by baffling, the *Alert's* being the first and the *Nebraska's* the last boilers of this type.

4. The Hohenstein;
5. The Thornycroft, *Cushing.*

The tests of the boilers of the *Cincinnati* and *Alert* are affected, to some extent, by the fact that heated draft was used, and from the fact that different coal was used, and some of the tests were of short duration; but it is probable that all of these tests are affected to a much greater extent by the one source of error which cannot be eliminated, namely, *difference in the firing.* How great this difference may be will be seen from the records of the first six tests of the Hohenstein boiler as given in regular order in the table, and as plotted in the chart giving line marked "Hohenstein, poor firing." The firemen employed for these tests were unsatisfactory, and their places were taken by men who, although of little experience, followed faithfully the instructions carefully laid down by the Board. The results were better and very much more uniform.

These points have been plotted with rates of combustion per square foot of grate surface as abscissæ and evaporation per

pound of coal from and at 212 degrees as ordinates, the curves being drawn for each boiler. These curves probably represent very nearly the average performance of the various types at the different rates of combustion.

The extent to which boilers may differ will be seen by comparing the record of the Thornycroft with the B. & W., *Nebraska*. The Thornycroft shows a very high performance at a rate of 7.58 pounds of coal per square foot of grate surface. This might be expected, from the fact that the heating surface is very much larger than required for that rate, and from the fact that the water circulation is very free. All of the water evaporated may easily be accounted for by the row of tubes next the fire.

When forced, the difference becomes very great, and the effect of this loss in efficiency has a very material influence upon the comparative weight of the two boilers, as will be pointed out later.

In the early development of the water-tube boiler great importance was attached to the rapidity of circulation of the water. That this does have some effect upon the performance of the boiler is not denied, but the experiments of Thornycroft and others about 1896 tended to show that in the various approved types the difference due to various arrangements of tubes was not material, provided, of course, the arrangement is not such that circulation will fail.

The effect of variations in the circulation in gases, however, is very marked.

To preserve the efficiency when forced a boiler must be baffled, by water walls, as in the Normand, or by brick and iron baffles, as in the B. & W. types.

Some boilers lend themselves very easily to baffling; others can not be baffled successfully. It is interesting to compare two types of boilers in this respect.

Fig. 1 represents B. & W., Fig. 2 the Hohenstein.

It is probable that the path of the gases would be about as shown, tending to keep somewhat the same sectional area, and the area of the effective heating surface would be as shown by the shaded area.

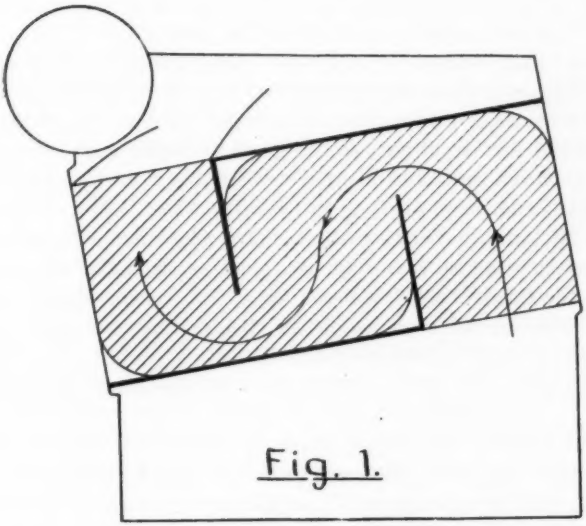


Fig. 1.

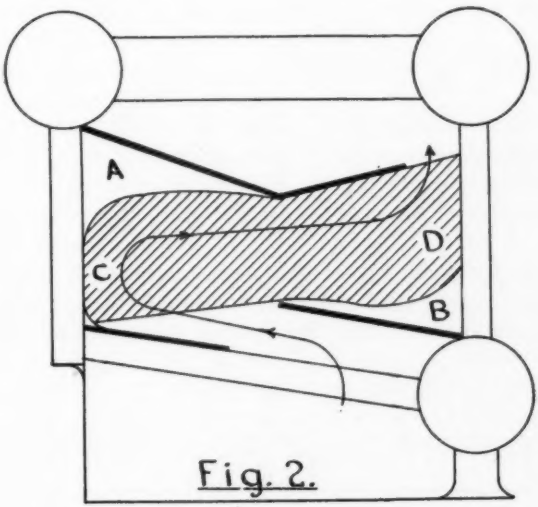


Fig. 2.

It is quite certain that in the Hohenstein boiler a larger part of the tube surface at A and B would be ineffective.

Where the direction of the gases is along the tubes, the resistance being less than around and between the staggered tubes, the cross-section would tend to diminish, and in the Hohenstein boiler the larger part of the gases probably travel from C to D, between the tubes slanting up from left to right, rather than across the tubes slanting in the other direction.

The Niclausse boiler cannot be effectively baffled without destroying its principal reason for existence—that is, the ease with which the tubes can be removed—and the wastefulness of this boiler under forced draft would be a more effective bar to its being forced than its defective circulation.

Some curious points may be observed in some small-tube types.

In the Thornycroft *Daring* type, as installed on the *Missouri* and most of the destroyers, fairly efficient baffling has been intended; but, in building, an opening large enough to put the

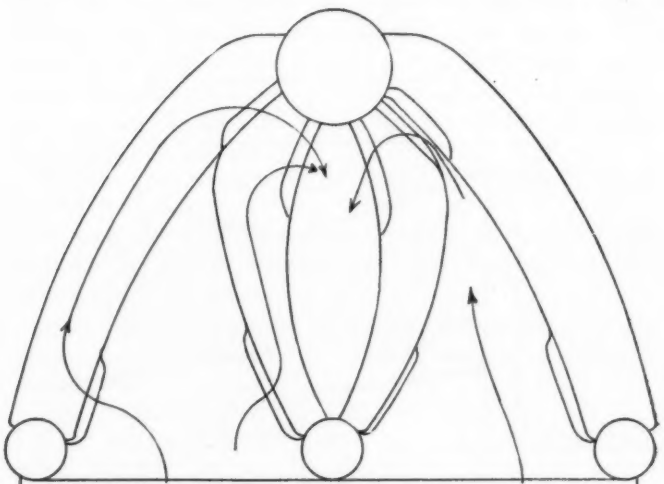


Fig. 3.

hand through has been left at the crown of the furnace, which short-circuits the gases direct into the uptake. This is illustrated in Fig. 3. The left-hand section illustrates what is intended, the right-hand shows what happens. On the *Missouri* this space has been filled with special fire brick.

This has been remedied in the latest type of the Thornycroft-Schultz, but there is another point worth noting. In most cases, in order to get the ratio of heating to grate surface considered necessary, the boiler has been extended beyond the grate, putting in a bridge wall, as shown in Figs. 4 and 5.

The effect of this is best seen from the plan, Fig. 5.

The draft being through the tubes at right angles to the grate, the tubes from A to B are cut out of the circulation.

The torpedo boats *Porter* and *Morris* (*Talbot* and *Gwin*) have boilers identical in type except for the gas passage.

The *Morris* is a return-fire Normand. In the *Porter's* boiler the tubes on the furnace side are open at the ends, at the top, and on the uptake side in the middle, at the bottom, Fig. 6.

It is difficult to maintain a fire of even thickness front and back, and the *Porter* type is very sensitive to uneven firing, a heavy fire in front causing the front of the boiler to get an excess of unburned gas and the back half an excess of air.

In the *Morris* type the grate can be fired in front and pushed back without great loss of efficiency.

As a general thing a boiler having a gas passage from front to back is preferable, since, especially when the grate is longer than it is wide, it is easier to maintain an even fire across the grate than it is in the direction of the length, and a much better opportunity of mixing gas and air follows.

In the Mosher *Florida* type a novel scheme of baffling has been adopted. This boiler is identical with the Yarrow except for a slight curvature of the tubes. A perforated plate has been placed on the outside row of tubes. By offering greater resistance to the air passage this would have the effect of distributing the gases more thoroughly over the heating surface, but it would also tend to bank up the air pressure necessary to burn a certain amount of coal.

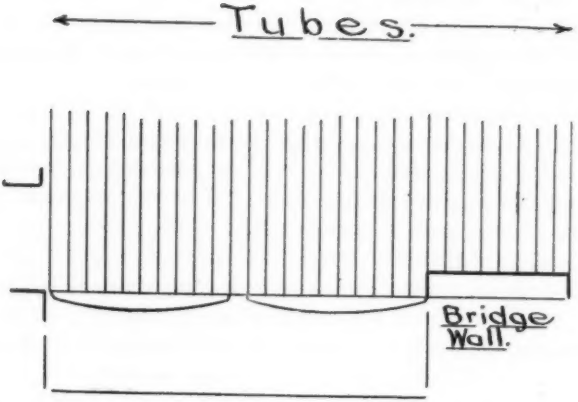


Fig. 4.

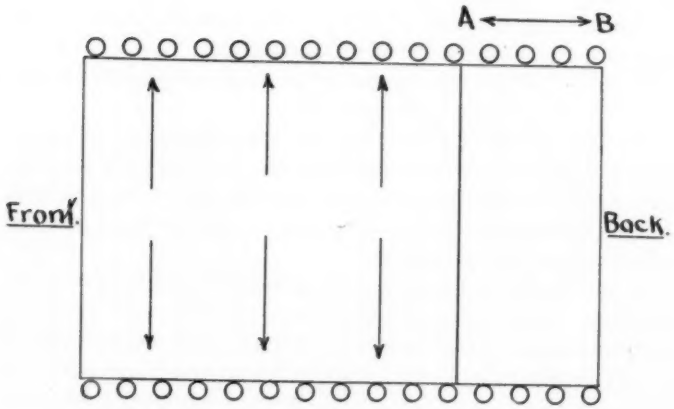


Fig. 5.

It is unfortunate that no complete tests on a Normand boiler are available. Some tests have been made abroad, but the conditions are not known, and as a general thing it is unsafe to rely on records other than our own.

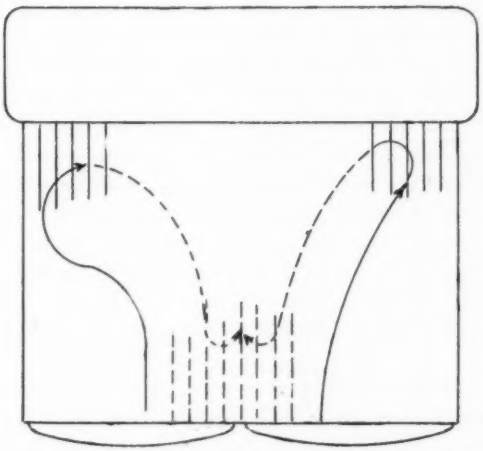


Fig. 6.

The performance of boats having Normand boilers leads to the belief of a high efficiency. The *Porter*, *Dupont*, *Morris*, *Talbot*, *Gwin*, all have modified Normand boilers, which are well known for steam making qualities. It is on the boats built on Normand's own designs, however, that the best results are obtained, and there is one small point of difference which is worth noting:

In the Herreshoff type the uptake has been taken from the top of the boiler, Fig. 7.

In the *Bagley* type, Fig. 8, while the tubes are open at A, as in the Herreshoff, the uptake is carried around the front of the boiler, which adds materially to the effectiveness of the lower front half of the boiler.

In the *Bagley*, *Craven* class, something over 30 I.H.P. per square

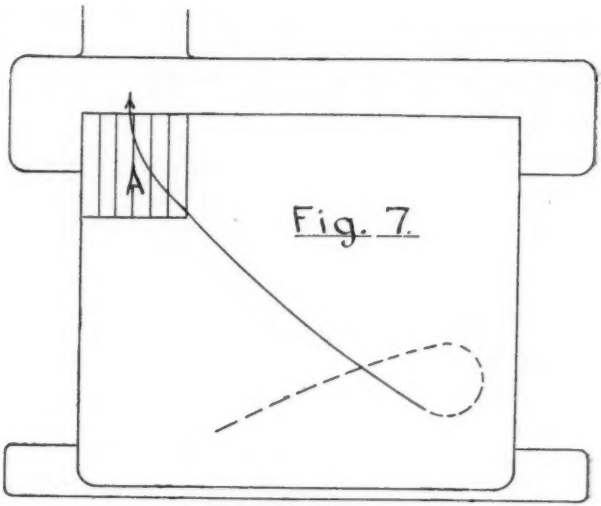


Fig. 7.

Herreshoff.

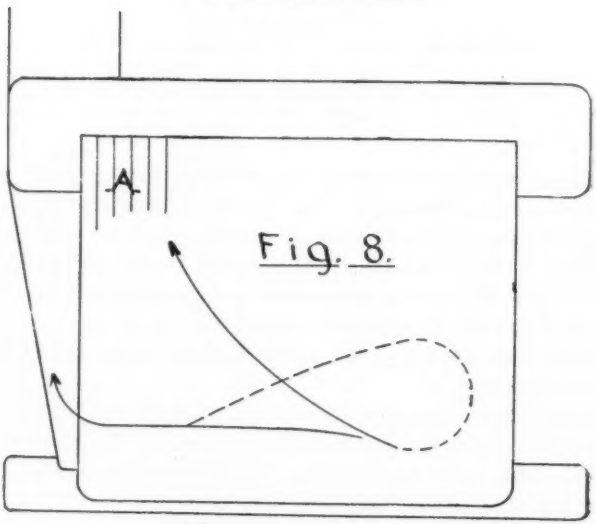


Fig. 8.

Normand.

foot grate surface has been developed. In our practice this is unprecedented. Foreign trials have recorded as high as 40 I.H.P. per square foot grate surface.

In a memorandum forwarded to the Bureau of Steam Engineering two years ago an attempt was made to analyze the performance of these boats, but this is difficult, owing to the uncertainty of the engine performance.

An attempt was made to compute the steam per I.H.P. from the cards, and an estimate of 20 pounds of steam per I.H.P. for all purposes was arrived at.

For a cylinder ratio of about 1 to 4 this is probably a low enough estimate, although it has been put as low as 14 pounds. Assuming the accuracy of this estimate, as well as the accuracy of the coal burned, 60 pounds per square foot grate surface per hour, the quantity of steam required would be accounted for by an equivalent evaporation of 9.76 pounds. Assuming the accuracy of this, it is easy to see how more than 30 I.H.P. per square foot of grate was obtained.

There is no good reason why a boiler should not be designed which would show the same efficiency at a rate of combustion of 60 pounds of coal per square foot of grate surface as at a much lower rate. The fact that boilers at present designed do not show such efficiency can only be due to the fact that the furnace volume is insufficient to complete combustion, and the heating surface is unable to take up the heat, due either to improper baffling or to insufficiency.

Such a boiler would be heavy per unit of grate surface, and possibly would be heavy per unit of power developed, but the saving in the coal bill would much more than make up for this increase.

The weight of coal to be carried by a vessel has apparently never been considered in connection with the boiler design, and until this is done there can be no rational solution of the boiler problem.

In order to illustrate this, it is proposed to take a problematical design, using the data from Table I, or Plate I, which give the results of evaporative tests of various boilers at hand.

It must be noted that the *Cushing's* boiler is not claimed to be an economical one of the Thornycroft type, but it is the only one of which complete and reliable data of tests are at hand, and is taken with the other boilers for sake of illustration. Neither is it suggested that boiler tests must be taken as a basis for designs, but it is insisted that such tests offer the only basis that we now have for comparison of different designs.

It is proposed to boiler a vessel to develop 10,000 I.H.P., assuming that for main and auxiliary machinery an actual consumption of about 17.76 pounds of water is necessary, equivalent to about 20 pounds from and at 212 degrees, with a feed temperature of 150 degrees and steam pressure of 250 pounds (factor of evaporation, 1.126), to select a type of boiler to give best results, considering weight of boiler and coal only, under the following conditions:

(a) For a battleship, when maximum power is required for about 12 hours.

(b) For a scout, where maximum power must be sustained for 96 hours.

Table II shows the actual weights of boiler and water to steaming level, same with coal added for 12 hours steaming at full power and same with coal added for 96 hours steaming at full power for the Hohenstein, 3 types of Babcock & Wilcox and Thornycroft (*Cushing*) boilers. These results have been calculated from results of evaporative tests given in Table I, and have been plotted on Plates II, III and IV to give graphical representation of results.

It will be seen from Plate II that with the weights of boiler and water alone necessary, calculated on this basis, the improved Babcock & Wilcox boiler becomes slightly lighter than the Thornycroft (*Cushing*) at a coal consumption just below 40 pounds per square foot of grate.

From Plate III it will be seen that the weight of boiler and water plus coal for 12 hours at full speed makes the Babcock & Wilcox improved type lighter than the Thornycroft (*Cushing*) at a little over 35 pounds coal consumption, and the Hohenstein as light at about 50 pounds consumption.

From Plate IV it will be seen that the Babcock & Wilcox becomes lighter than the Thornycroft (*Cushing*) at about 30 pounds coal consumption, and the Hohenstein lighter at about 40 pounds.

TABLE I.—EVAPORATIVE TESTS OF VARIOUS BOILERS.

TABLE 1.—EVAPORATIVE TESTS OF VARIOUS BOILERS.

Type of boiler.		Duration of test, hours.	Draft in ash pits, inches of water.	Coal per sq. ft. of grate, pounds.	Water from and at 212° per lb. dry coal.	Temp. gases, in base smoke pipe.	Steam pressure per gauge, pounds.	No. of point on curve.	Remarks.
					lbs.	*F.°*			
Babcock and Wilcox, **Nebraska.** Test made on shore.	G. S. = 111.72 sq. ft. H. S. = 4,682 sq. ft.	7	...	24.48	10.70	673	...	N_1	Closed ash pit.
	Weight, dry..... 97,133 pounds.	8	...	26.46	10.89	650	...	N_2	Closed ash pit.
	water..... 19,532 pounds.	8	...	28.56	10.57	680	...	N_3	Closed fire room.
		7¼	...	29.99	10.97	688	...	N_4	Closed fire room.
	wet..... 116,665 pounds.	8	...	31.46	10.83	716	...	N_5	Closed ash pit.
		5	...	36.09	10.80	693	..	N_6	Closed fire room.
Babcock and Wilcox, **Cincinnati.** Tests made on shore.	G. S. = 6,325 sq. ft. H. S. = 2,640 sq. ft.	8	.25	19.61	11.03	466	209.3	C_1	.....
	* Reduced grate = 52 sq. ft.	8	.107	20.19	11.51	493	206.6	C_2	Draft heated to 458°.
	Weight, dry ..... 53,304 pounds.	6	1.42	33.51	10.49	608.6	210.6	C_3	Draft heated to 569°.
	water..... 9,498 pounds.	6	1.37	35.08	10.41	570.6	207.4	C_4	.....
		4	1 45	47.81	12.17	637	209.8	C_5	Reduced grate.* Draft heated to 674°.
	wet..... 62,802 pounds.	4	1.37	50.38	10.14	640	213.6	C_6	Reduced grate.*
		3¼	1.685	59.23	9.63	900	210.8	C_7	.....
		...	.23	15.35	10.93	...	...	A_1	.....
		...	.26	16.16	11.33	...	...	A_2	.....
Babcock and Wilcox, **Alert.** Test on shore.	G. S. = 48 sq. ft. H. S. = 2,125 sq. ft.	...	.43	19.85	10.72	...	...	A_3	.....
	Weight, dry..... 46,110 pounds.	...	.61	21.14	10.97	...	...	A_4	.....
	water..... 7,660 pounds.	...	.55	22.09	10.70	...	...	A_5	.....
		6	1.14	28.82	10.66	521	218	A_6	Anthracite coal.
	wet..... 53,770 pounds.	6	1.82	39.93	10.05	581	...	A_7	Draft heated. Jet and blower draft.
		6	1.91	41.88	10.06	567	220	A_8	Draft heated.
		6	1.93	45.39	9.41	619	219	A_9	Draft heated.
Thornycroft, **Cushing.** Test made after vessel was commissioned.	G. S. = 38 sq. ft. H. S. = 2,451 sq. ft.	1.5	Assist	7.58	12.22	371.5	250	T_1	.....
	Weight, dry..... 20,160 pounds.	11.43	½	24.12	11.43	536.5	250	T_2	.....
	water..... 4,480 pounds.	11.5	3	40.23	8.94	653.0	250	T_3	.....
		1.0	4	66.32	6.65	713.0	250	T_4	.....
	wet..... 24,640 pounds.	8	—.05	24.1	8.73	594	265.4	H_8	
		6	1.08	34.5	8.86	784.7	274.4	H_9	
		4	2.0	52.4	8.48	1,001.6	276.1	H_{11}	Poor firing.
		8	0	21.3	10.28	675	272.8	H_4	
		6	1.064	35.2	9.87	681	274	H_{10}	
		3¼	1.968	47.8	8.28	1,125.7	272	H_{13}	
Hohenstein.....	G. S. = 50.14 sq. ft. H. S. = 2,174 sq. ft.	8	—.05	19.4	9.91	562.5	275	H_3	.....
	Weight, dry..... 46,568 pounds.	6	1.07	31.2	9.68	654	275	H_8	.....
	water..... 7,559 pounds.	4	2.10	43.4	9.42	687.5	275	H_{11}	.....
		8	—.05	20.2	9.84	548.4	275	H_3	.....
	wet..... 54,127 pounds.	8	—.045	18.3	10.16	521	275	H_1	.....
		6	.99	27.4	9.70	580	275	H_7	.....
		4	2.1	52.8	9.48	717	275	H_{15}	.....
		6	1.0	46.3	9.00	766	275	H_{12}	.....
		8	—.2	22.7	10.11	568	275	H_5	.....
		4	2.0	62.4	8.53	800	275	H_{16}	.....
		3	3.0	71.7	8.39	943	275	H_{17}	.....

TABLE II.—COAL CONSUMPTION PER SQUARE FOOT GRATE PER HOUR.

.....	B. & W., *Nebraska.*	B. & W., *Cincinnati.*	B. & W., *Alert.*	Hohenstein.	Thornycroft, *Cushing.*
20 pounds.					
Weight of boiler per square foot of grate, pounds	1,044	992.9	1,120	1,080	880
Evaporation per pound of coal (from curve)	.....	11.25	10.9	10.1	11.6
Pounds of coal for 1 I.H.P. = 20 pounds water	.....	1.777	1.883	1 98	1.724
10,000 I.H.P., per hour	.....	17,770	18,330	19,800	17,240
Grate surface necessary, square feet	.....	889	916.5	990	862
Weight of boiler and water, tons	.....	394	458.2	477.3	338.6
coal for 96 hours, tons	.....	761.6	785.5	848.7	738 9
Total weight of boiler and coal for 96 hours, tons	.....	1,155.6	1,243.7	1,326.0	1,077.5
Weight of coal for 12 hours, tons	.....	95.2	98.2	106.1	92.4
Total weight of boiler and coal for 12 hours, tons	.....	489.2	556 4	583.4	431.0
25 pounds.					
Evaporation per pound of coal (from curve)	10.8	11.0	10.7	9.9	11.3
Pounds of coal for 1 I.H.P = 20 pounds water	1.852	1.818	1.869	2.0202	1.790
10,000 I.H.P., per hour	18,520	18,180	18,690	20,202	17,900
Grate surface necessary, square feet	741	727	748	808	716
Weight of boiler and water, tons	345.4	322.3	374.0	389.6	281.3
coal for 96 hours, tons	793.7	779.1	801 0	865.8	767.2
Total weight of boiler and coal for 96 hours, tons	1,139.1	1,101.4	1,175.0	1,254.8	1,048.5
Weight of coal for 12 hours, tons	99.2	97.4	100.1	108 2	95.9
Total weight of boiler and coal for 12 hours, tons	444.6	419 7	474.1	497.2	377.2
30 pounds.					
Evaporation per pound of coal (from curve)	10.95	10.8	10.45	9.75	10.54
Pounds of coal for 1 I.H.P. = 20 pounds water	1.826	1.852	1.914	2.051	1.897
10,000 I.H.P., per hour	18,260	18,520	19,140	20,510	18,970
Grate surface necessary, square feet	609	617	638	684	632
Weight of boiler and water, tons	283.7	273.5	319.0	329.7	248.3
coal for 96 hours, tons	782.6	793.7	820.3	879.0	813.0
Total weight of boiler and coal for 96 hours, tons	1,066.3	1,067 2	1,139 3	1,208.4	1,061.3
Weight of coal for 12 hours, tons	97.8	99 2	102.5	109.9	101.6
Total weight of boiler and coal for 12 hours, tons	381.5	372 7	421.5	439.6	349.4
35 pounds.					
Evaporation per pound of coal (from curve)	10.8	10.6	10.25	9.6	9.75
Pounds of coal for 1 I.H.P. = 20 pounds water	1.852	1.887	1.951	2.082	2 051
10,000 I.H.P., per hour	18,520	18,870	19,510	20,820	20,510
Grate surface necessary, square feet.	529	539	557	595	586
Weight of boiler and water, tons	246.5	238.9	278.5	286.9	230.2
coal for 96 hours, tons	793.7	808.8	836.1	892.3	879.0
Total weight of boiler and coal for 96 hours, tons	1,040.2	1,047.7	1,114.6	1,179.2	1,109.2
Weight of coal for 12 hours, tons	99.2	101.1	104.5	111.5	109.9
Total weight of boiler and coal for 12 hours, tons	345.2	340.0	383.0	398 4	340.1
40 pounds.					
Evaporation per pound of coal (from curve)	10.8	10.4	10.05	9.4	9.0
Pounds of coal for 1 I.H.P. = 20 pounds water	1.852	1.923	1.991	2.1276	2.222
10,000 I.H.P., per hour	18,520	19,230	19,910	21,276	22,220
Grate surface necessary, square feet	463	481	498	532	555.5
Weight of boiler and water, tons	215.8	213.2	249.0	256.5	218.2
coal for 96 hours, tons	793.7	824.1	853.4	912.0	952.4
Total weight of boiler and coal for 96 hours, tons	1,009.5	1,037.3	1,102.4	1,168.5	1,170.6
Weight of coal for 12 hours, tons	99.2	103.0	106.7	114.0	119.0
Total weight of boiler and coal for 12 hours, tons	315.	316.2	355 7	370.5	337.2
50 pounds.					
Evaporation per pound of coal (from curve)	.....	10.0	.....	9.1	8.07
Pounds of coal for 1 I.H.P. = 20 pounds water	.....	2.0	.....	2.198	2.478
10,000 I.H.P., per hour	.....	20,000	.....	21,980	24,780
Grate surface necessary, square feet.	.....	400	.....	440	498
Weight of boiler and water, tons	.....	177.5	.....	212.1	195.6
coal for 96 hours, tons	.....	857.2	.....	942.0	1,065.7
Total weight of boiler and coal for 96 hours, tons	.....	1,034.5	.....	1,154.1	1,261.3
Weight of coal for 12 hours, tons	.....	107.2	.....	117.8	133.2
Total weight of boiler and coal for 12 hours, tons	.....	284.5	.....	329.9	328.8
60 pounds.					
Evaporation per pound of coal (from curve)	.....	9.58	.....	.....	7.19
Pounds of coal for 1 I.H.P. = 20 pounds water	.....	2.0877	.....	.....	2.782
10,000 I.H.P., per hour	.....	20,877	.....	.....	27,820
Grate surface necessary, square feet.	.....	348	.....	.....	464
Weight of boiler and water, tons	.....	154.3	.....	.....	182.3
coal for 96 hours, tons	.....	894.7	.....	.....	1,192.0
Total weight of boiler and coal for 96 hours, tons	.....	1,049.0	.....	.....	1,374.3
Weight of coal for 12 hours, tons	.....	111.8	.....	.....	149 0
Total weight of boiler and coal for 12 hours, tons	.....	266.1	.....	.....	331.3

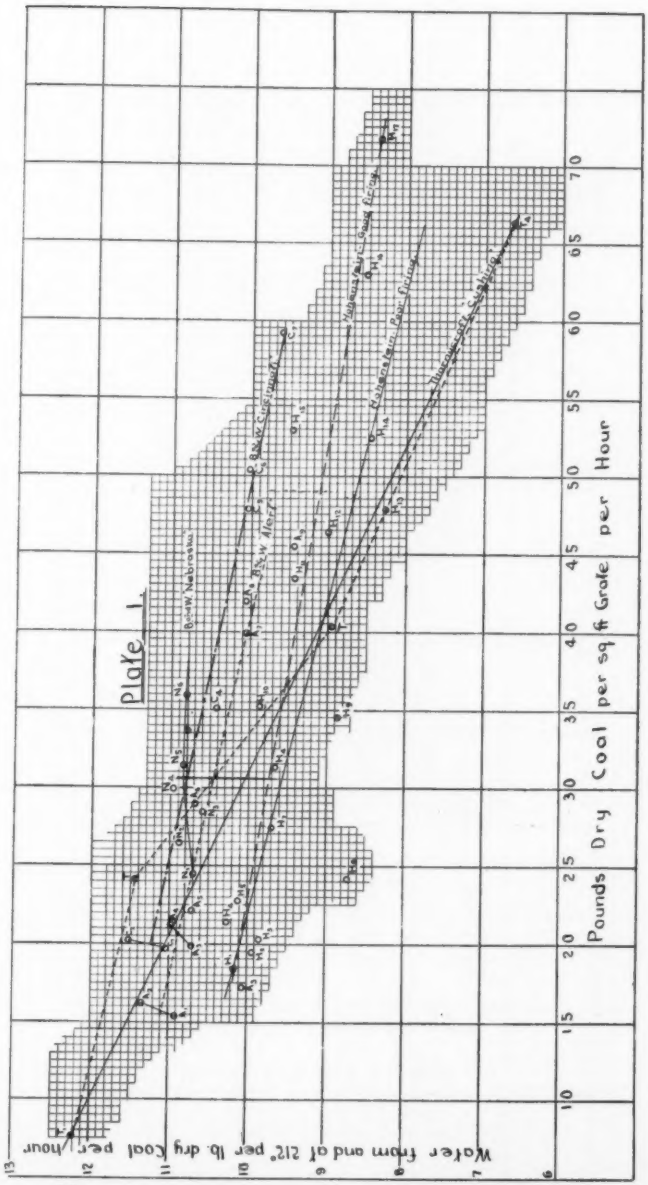


Plate I.
Water from and at 212° per lb. dry Coal per Hour
Pounds Dry Coal per sq ft Grate per Hour
10
15
20
25
30
35
40
45
50
55
60
65
70
6
7
8
9
10
11
12
13

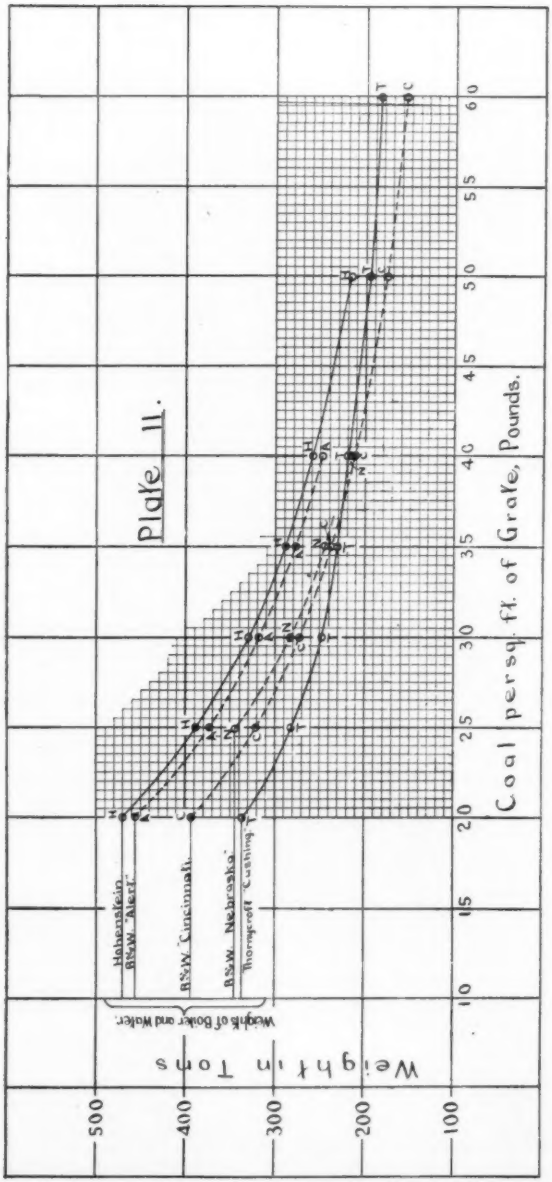


Plate II.
Coal per sq. ft. of Grate, Pounds.
10
15
20
25
30
35
40
45
50
55
60
Weight in Tons
100
200
300
400
500
Weights of Boiler and Water.
Hohenstein
B.&W. Alert
B.&W. Cincinnati
B.&W. Nebraska
Thornycroft Cushing

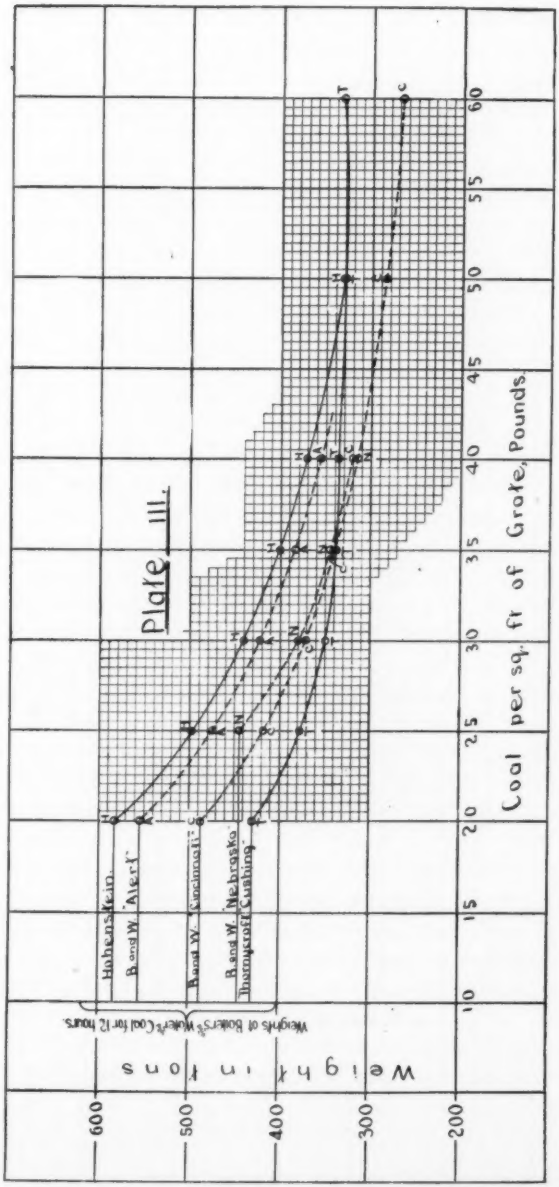


Plate III.
Weights in tons
Coal per sq. ft of Grate, Pounds
Weights of Boilers & Water & Coal for 12 hours.
Hohenstein.
Bond W. 'Alert'
Bond W. 'Cincinnati'
Bond W. 'Nebraska'
Thornycroft 'Cushing'

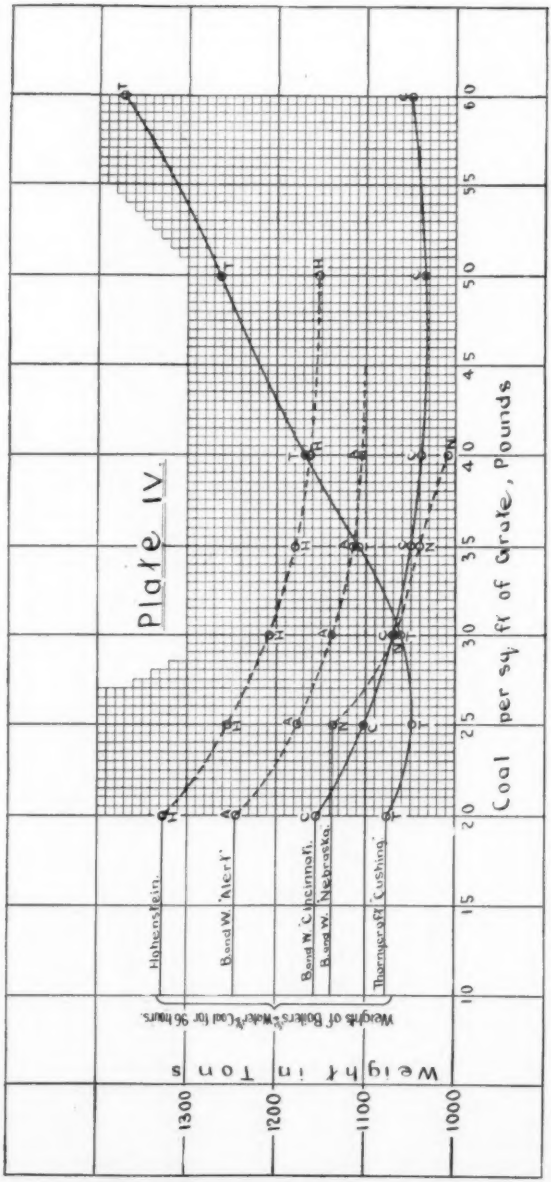


Plate IV.
Coal per sq. ft of Grate, Pounds
10
15
20
25
30
35
40
45
50
55
60
Weight in Tons
1000
1100
1200
1300
Weights of Boilers & Water & Coal for 96 hours.
Hohenstein.
Bond W. 'Alert'
Bond W. Cincinnati.
Bond W. Nebraska.
Thornycroft 'Cushing'

It is unfortunate that no complete tests with actual weights for other boilers are accessible, as these results should be carefully considered when a selection of a type of boiler is made for a new vessel. Extensive tests on any type of boiler should be made before it is approved for use in vessels of the Navy, and money so expended by the Government would be well repaid in the future saving of expense in maintenance of cruising ships.

It is not believed that more than 40 pounds of coal per square foot of grate per hour can be maintained for 96 hours, nor more than 45 to 50 pounds for 12 hours under service conditions.

The Normand boiler has not been considered, since its performance is a matter of doubt, owing to lack of complete and accurate data, but it certainly deserves a high place.

The boiler question seems to be narrowed down to a few types. When lightness and ability to stand high forcing for a short time, with reasonable economy, is required, a bent-tube boiler should be used, with the Normand probably in the lead. For general service and reasonable forcing for long periods, with economy, a straight-tube boiler is preferable, with the Babcock & Wilcox probably in the lead in this country, but too sharp a line cannot be drawn between these types. The Normand is lighter per unit of grate surface, because the tubes are smaller and casings lighter. With small tubes and weights of casings and fittings cut to the same extent, the Babcock & Wilcox would not be materially heavier.

The Normand will, undoubtedly, stand harder forcing, but the limit to which a boiler may be forced will eventually be placed at the maximum which can be maintained in service; that is, with dirty fires.

The Normand requires more floor space per square foot of grate, owing to the side drums; these also limit the width of grate, and in some cases necessitate an abnormally long grate. The length of grate will be materially lessened when boilers are designed for service conditions rather than for trial trips, and when the weight of coal is considered as part of the boiler weights.

The limit of grate for service conditions would seem to be about 7 feet, and the maximum consumption of coal about 40 pounds

per square foot of grate, though, as the grate is shortened, the rate of combustion may be increased somewhat.

Many small-tube boilers at present in service in torpedo boats would be materially increased in weight if the casings and fittings were increased to the proper extent and if the tubes were made thick enough to give expectation of lasting a reasonable time.

It has been the object of this memorandum to point out the evils of classifying boilers by their rate irrespective of what they can do, also to call attention to the fact that while trial results may be obtained by burning coal without limit, the result of a few days' hard steaming would often tell in favor of the heavier boiler.

It has been the practice for some years past to design ships for results which it is frankly admitted are not expected to be reached in service. The fact that they are rarely reached is no doubt due to causes for which the designer is not responsible, but it is high time that an effort be made to find out what can be done both in regard to speed and economy. Speed is certainly only second in importance to gun fire, and the same interest in speed trials and training of firemen that is devoted to target practice would lead to results of the utmost importance.

There should also be an economy requirement in our contracts, which important provision we have so far neglected.

It is just as hard to train firemen as it is to train gun pointers, but there is this important difference, that it cannot be done in port, nor can it be done by steaming at easy, natural draft.

This is well illustrated in Plate I, where the first six tests of the Hohenstein boiler with the poor firing, done by men who would not be trained, are plotted separately from the later results obtained by firemen willing to do as told, and who finally became trained to the work. It will be noticed that at natural draft, or a consumption up to 20 pounds per square foot of grate, the results were about the same, but as the consumption increased the difference in results became marked.

All ships fitted with water-tube boilers should be required to steam, whenever possible, with reduced power at the rate of combustion necessary to maintain full power. The difference in

economy thus occasioned would be more than counterbalanced by the training given the men. This would entail an alteration of the present Navy Regulations, but it is a step that it is believed would result in an advantage to the Government and the increased efficiency of the Service.

NOTE.—All average pressures given in tables for Tests 1, 2, 3, 4, 5, 6, are corrected for gauge error, —2.3 pounds.

STEAM TURBINES,

WITH A SPECIAL REFERENCE TO THEIR ADAPTABILITY TO THE PROPULSION OF SHIPS.

By Ernest N. Janson, Associate Member.

Progressiveness, together with keen competition, places the demand for speed, in vessels intended for higher and more exacting service duties, at a figure such as to necessitate ever increased power installations. This has augmented the power and size of the engines and their speed of rotation to such a degree that, to go much beyond the present practice, would no doubt endanger their safe running and render intelligent and concentrated supervision a most difficult task.

This may be best illustrated, on the one hand, by the ordinary class of torpedo-boat engines, in which an enormous power is obtained on an extremely small allowance for weight and space, made possible only by a very high rotative speed and steam pressure, together with a construction in which each part must be produced from the highest grades of materials and the finest of workmanship, all in strict accordance with the most carefully and scientifically conceived designs and methods of manufacture. Despite this, however, most expensive and disastrous mishaps do frequently occur, which seem impossible to prevent, even by the exercise of the limit of both skill and precaution. On the other hand, a directly opposite extreme in engine construction is found in the great power units of the average high-speed cruiser or transatlantic liner, in which sometimes as much as 30,000 to 40,000 I.H.P., with from 60,000 to 70,000 I.H.P. in immediate contemplation, are developed in a pair of engines revolving their shafts at only from one-fourth to one-sixth the number of turns when compared with the former, and therefore necessitating an immense increase in both weight and space, many times that called for per

I.H.P. in engines of the type above referred to. With this in view it should cause no great surprise to find the steam turbine surrounded by a keen anticipation with regard to its fitness to take, if not wholly, at least partly, and especially in extraordinary cases, the place of the reciprocating engine. This interest is further developed on account of the special and peculiar advantages which present themselves by the application of the turbine as the motor to furnish power for marine propulsion.

APPLICATION TO VESSELS.

That the steam turbine for marine purposes is already beyond the experimental stage is best proved by its successful operation in a number of turbine-driven vessels, among which may be mentioned the Clyde passenger steamers *King Edward* and *Queen Alexandra;* the Channel steamers *Brighton* and *Queen;* the yachts *Emerald*, *Lorena*, *Tarantula* and *Revolution;* the *Turbinia*, and the torpedo-boat destroyers *Velox*, *Viper* and *Cobra* (the latter two unfortunately lost). That conjecture with regard to the suitability of these motors for various classes of ships has been converted into a certain degree of confidence may also be judged by the projection of steam turbines for motive power in a 17-knot transatlantic liner for the Allan Line, some scout ships for the U. S. Navy, with several smaller cruisers of high speed both for the British and German Admiralties.

FEATURES OF ADVANTAGE.

With reference to some of the more characteristic features of the steam turbine it may be mentioned that certain tactical advantages exist in its maintained efficiency and greater readiness for service, without the necessity for the usual exacting preparedness, while, in the saving of weight, space, cost of upkeep and in attendance lie some commercial superiority. Especially are these advantages apparent when the turbine is placed in comparison with the ordinary engine, when we note the perfect safety and ease with which almost any speed of shaft rotation may be reached without approaching that danger limit from overspeed or racing, to which, sooner or later, the ponderous and fast-moving reciprocating en-

gine is bound to be subjected. The following short citation, from the "Report concerning the Deisgn, Installation and Operation of the Turbine Engines of the S. S. *Revolution*," made to the Chief of the Bureau of Steam Engineering, in a measure substantiates the above: "The general ease with which the machines in question are cared for and handled is undoubtedly due to the great simplicity of the mechanism when compared with the reciprocating engine. As an engine it requires but little previous 'warming up,' no cylinder drains to be opened nor any general filling up of oil boxes, sight feeds and wick cups, the turning on or the shutting off of the main steam supply being the principal and almost the only operation remaining."

Equally important with the above are, the complete absence of vibration in the motor, the very minute quantities of oil necessary for its operation, and the more remote liability of complete breakdown, due wholly to the extreme simplicity of its component parts. The absence of any internal lubrication in the turbine makes it possible to return the condensed exhaust steam free from oil, which is of incalculable value for the efficient working of the boilers. In order more effectively to provide for this, however, it will be necessary to disassociate thoroughly the auxiliary exhaust connections from the main by arranging an entirely independent system of condensers, feed tanks and pumps.

Steam turbines, unlike piston engines, are not affected appreciably by priming of the boilers, except for the temporary reduction of their speed. The danger from concussion or the heavy and sudden "knocks," caused by the action of water lodging between the cylinder heads and pistons in reciprocating engines, may be entirely disregarded, as far as danger goes, in an installation with these motors.

Superheated steam may be used within reasonable limits in the turbine without nearly the same distorting effects upon its moving parts noted in the reciprocating engine. In connection with this, however, owing to expansion of the vanes and discs when exposed to the increased temperature incidental to the use of superheated steam, it should be mentioned that the origi-

nally small vane clearance has become dangerously reduced in some cases, even to the point of stripping vanes from their places of support.

The first cost of the turbine engine compares favorably with that of the ordinary engine, and diminishes with high powers in a more rapid proportion than that for reciprocating engines.

The exceptional economy of the turbine at high speeds, together with its capacity for considerable increase in power beyond that for which rated, without the entailment of dangerous or critical conditions of stress, promises to be of especial advantage for certain purposes, for example, in vessels of the transatlantic passenger service.

WEIGHT AND SPACE.

Other advantages of especial value, when considered in connection with marine installations, are found in the decidedly decreased weight and space required for steam turbines in comparison with the average reciprocating engine. This is especially true when comparison is made with the ordinary, slow-running, commercial type of engine, in which the weight expenditure per equivalent I.H.P. readily reaches from 50 pounds to 75 pounds or more, this weight representing engine weight only. The volumetric space occupied by the turbine motor, as well as the weight required for installation in vessels, will probably come very closely within the limits usually allowed in torpedo-boat engine designs, or between 10 and 15 pounds of weight and between .15 and .2 cubic feet of space, all per equivalent I.H.P.

When this same comparison is made with engines used for battleships the difference is vastly to the advantage of the turbine, the engines of the latter class of ships ranging between 45 to 55 pounds in weight and from .7 to .8 cubic foot in space, per equivalent I.H.P.

The above being an approximate comparison between turbine and engine as motors without considering the auxiliaries, the difference in actual space and weight when the whole machinery is considered will not be quite in proportion to the figures given, as additional weight and space must be allowed for the larger auxiliaries necessary with the turbines.

INSTALLATION.

In the application of a motor so widely different to the one now used, it is interesting to note the changes involved by incorporating the steam turbine in the general machinery arrangements of ships. These changes occur chiefly in the size and position of the shafting, in modifications of the propellers, and in the necessity for increased capacity and efficiency of certain auxiliaries, upon which the economical working of the turbine largely depends.

The shafting itself becomes smaller in proportion to the increased speed of rotation, and in the majority of cases, must be placed at a certain incline in the vertical plane to allow its center to be raised at the forward end to fit in with the turbine. The propellers, rotating at a comparatively greater number of revolutions, are made smaller and of a finer pitch ratio, and, where the speed of rotation is very high, a set of multiple screws may have to be fitted to each shaft.

CONDENSERS AND PUMPS.

A high vacuum being of especial advantage in the steam turbine, installations with this motor should be provided with particularly efficient adjuncts for meeting this demand. The main condensers and air pumps, therefore, should be designed with a view to obtain the highest possible efficiency, and, in order to further this purpose, they should be connected up entirely independent of the auxiliary machinery system. On the other hand, with a higher vacuum the density of the exhaust steam is rapidly growing less and its volume is thereby correspondingly greatly augmented. To what extent this is taking place may readily be ascertained by consulting the tables containing the properties of saturated steam, showing approximately an increase in volume four-fold by a change in the vacuum from 24 to 28½ inches. This necessitates considerably enlarged exhaust passages between the turbine and the condenser as well as an adequate allowance of additional space between its condensing surfaces. As far as is now known, the proportion to which this increase should be carried is not fully established by practice in marine installations

intended for longer and less interrupted service. But assuming equal steam consumption in both turbine and piston engine, the necessity of an increase in condenser capacity for the former will probably be required, for the following reasons: First, because of the lower temperature corresponding to the higher vacuum generally considered to be required by the turbine to produce equal efficiency to that of a reciprocating engine, with consequent smaller difference between this temperature and the mean temperature of the circulating water entering and leaving the condenser; second, on account of the greater latent heat in the steam at the lower pressure.

With reference to this matter, Whitham, "Steam Engine Design," page 283, gives the following for condensing surface:

$$S = \frac{W \times L}{CK\,(T_1 - t)},$$

in which

S = condensing surface in square feet;
W = total steam used in pounds;
L = latent heat of steam at T_1;
T_1 = temperature of steam in condenser;
t = mean temperature of circulating water.

C and K are constants in which the efficiency and conductivity of the cooling surface is involved.

The *Turbinia's* condensers have about two square feet of cooling surface per I.H.P., but in the yacht *Revolution*, above referred to, was considerably less, or only about one square foot per I.H.P., no difficulty being experienced in maintaining an even vacuum of a little over 27 inches for the time tried. In stationary turbine installations the practice varies between 2 square feet and 2½ square feet of condensing surface per equivalent I.H.P., but they are almost universally designed for 28 inches vacuum or better.

If air leaks through the glands around the turbine shafts can be guarded against effectively and the exhaust connections are made short, there should be no special need for increased capacity in the air pumps, but they should be of a design such as to insure a vacuum under all conditions of not less than from 2 to 2½

inches under the barometer. To maintain such a vacuum, a good air pump is, of course, of primary importance, but, besides that, it will be found necessary to arrange for a greater supply of condensing water, chiefly because of the much smaller difference in the initial and final temperature of the injection water. The necessity for an increase in the amount of circulating water may, perhaps, be appreciated by the following comparison.

Assuming 28 inches vacuum:

Quantity of cooling water in pounds per pound of steam =

$$Q = \frac{1114 + 0.3\,(T_1 - T_3)}{T_2 - T_0},$$

in which

T_1 = temperature of steam in condenser = 100 degrees Fahrenheit;

T_0 = temperature of cooling water entering condenser = 65 degrees Fahrenheit (assumed, rather low);

T_2 = temperature of cooling water leaving condenser = 85 degrees Fahrenheit (assumed);

T_3 = temperature of water condensed from the steam = 90 degrees Fahrenheit (assumed);

or

$$Q = \frac{1114 + 0.3\,(100 - 90)}{85 - 65} = 56 \text{ pounds.}$$

Assuming 26 inches vacuum, with same notation as above:

T_1 = 125 degrees Fahrenheit;

T_0 = 65 degrees Fahrenheit;

T_2 = 95 degrees Fahrenheit;

T_3 = 115 degrees Fahrenheit;

or

$$Q = \frac{1114 + 0.3\,(125 - 115)}{95 - 65} = 37 \text{ pounds.}$$

The hotwell temperature T_3, in the former case, being 25 degrees Fahrenheit less than in the latter, will necessitate an elevation in the temperature of the feed water obtained therefrom to maintain equal efficiency in the boilers in comparison with the latter case. In connection with this, it should also be men-

tioned that it seems quite possible to obtain a much higher hot-well temperature with 28 inches of vacuum than assumed above (90 degrees Fahrenheit), and may, in fact, be kept at an almost equal temperature with the exhaust steam (100 degrees Fahrenheit). This is very efficiently provided for in designs of condensers like the Alberger, in which the exhaust enters at the bottom of the condenser, which exhaust, after having been condensed, returns in form of a finely divided spray always meeting the inrush of new exhaust steam with which it becomes intimately mixed, at the same time absorbing part of its latent heat.

The capacity of the condensing plant intended for marine turbine practice must be verified by actual trials, which should include a determination of turbine efficiency in comparison with engine efficiency under certain conditions of vacuum. The results of such tests would then establish a basis upon which the determination of the proper condensing conditions required could be made, thereby preventing possible failures from undersize, or an excess of weight and space by too great an allowance in the various parts of its make up. The additional amount of cooling water for condensing purposes on board ship represents only the increased cost due to the additional power, weight and space of auxiliaries, but in certain cases of turbine installations for land purposes, where the water either has to be bought or pumped up and used over and over in cooling towers, it has been stated, that the turbine is barred out in competition with the reciprocating engine on account of the cost of water and extra pumping facilities required.

STEAM PRESSURE.

The high steam pressures now commonly used increase the economic results in steam turbines equally with those for reciprocating engines. This refers particularly to that class of turbines in which the steam acts by impulse at a very high velocity, by which the greater quantity of heat energy contained per pound of steam of the higher pressure is converted into kinetic energy, eventually absorbed by the turbine. In contradistinction to this it should be noted, in combined action and reaction turbines in which the ratio of expansion between successive vane-series is small, necessitating a large number, that losses due to fluid fric-

tion and leakages, as well as the corresponding enlargement of the machine itself, rather favor a lower pressure, or somewhere between 150 to 180 pounds per square inch. An unusual efficiency has been obtained with multicellular-action turbines of the Rateau type when operating with very low steam pressures, such, for instance, as are got by utilizing the exhaust steam from ordinary high-pressure engines. This is quite the reverse of the parallel case with piston engines, and, on account of its economy, has led to the actual application of such steam turbines in power plants for the conversion and utilization of the heat energy remaining in steam of low pressure.

SUPERHEAT.

The principal object in using superheated steam, whether in engine or turbine, is to obtain better economy in the consumption of fuel. A superheater meeting the requirements of durability and compactness, with minimum weight, if installed in warships, must from the start compensate in increased economy for the additional weight and space that must be allotted to its installation. The liability of the apparatus to failure through injuries readily sustained because of its location and severe exposure to the hot uptake gases, and the watchful attention required in handling, have been, and are now, arguments against its general adoption, especially on board ship. It may be mentioned incidentally, however, that the above fears are not shared by manufacturers of superheaters, nor generally experienced by engineers, many of whom are now using superheaters to great advantage for stationary purposes. The advantages experienced by using superheated steam lies chiefly in: First, decreased condensation in the cylinders if used in an engine and in the casing or nozzles when used in turbines; second, diminutions in the leakage past glands or through clearance spaces; third, increase in volume without a corresponding decrease in pressure.

The expansion being carried much further and more completely in the turbine than in the average engine, produces a correspondingly greater condensation, which, if prevented by superheating, must add greatly to the efficiency of the machine. The resistance to the revolving parts, due to fluid friction and

viscosity, is also considerably diminished by the greatly reduced density of superheated steam. The increase in volume, due to superheating, produces an equivalent increase of energy, and is of course as valuable in the engine as in the turbine. Thus, for example, steam at 115 pounds absolute has a volume of 3.8 cubic feet per pound and a pressure per square foot equal to 16,560 pounds; its $pv = 62{,}928$, which if superheated by 162 degrees F. becomes 82,128, representing a gain of $pv = 19{,}200$, and, as p is constant, this gain is entirely due to the augmentation of the volume. Because of this increase in volume it becomes necessary to provide for an adequate increase in the area of nozzles and passages intended for use in conjunction with superheated steam.

VACUUM.

Aside from the thermodynamic value in the attainment and maintenance of a high vacuum, it is of special and particular advantage in the steam turbine, both on account of the greatly diminished resistance caused by fluid friction in the low-pressure end, and on account of the increase in work by the additional drop in pressure when approaching the vacuum line, of which a mere glance at the card will give a convincing illustration. A greater ratio of expansion with a correspondingly lower terminal pressure may be taken care of with far greater facility and ease in the steam turbine than in the reciprocating engine, not only without nearly the same serious frictional losses, but with much less disturbance from internal condensation. This is principally due to a more constant temperature being maintained on each side of the turbine vanes between which the steam flow is always in one and the same direction and not, as in the reciprocating engine, alternating on either side of the piston with the frequency of each double stroke.

The influence upon the steam consumption at varying degrees of vacuum, when dry saturated steam and steam of 75 degrees Fahrenheit superheat is used, may be seen from the annexed Table I, made from actual tests with a 1250-K.W. Westinghouse-Parsons steam turbine for the Interborough Rapid Transit Co., New York.

TABLE I.

TESTS OF A 1250-K.W. WESTINGHOUSE-PARSONS STEAM TURBINE

TURBINE No. 41, TESTED

These tests, the calibration of the instruments, and the computations, were all verified by Julian Kennedy, Esq., Consulting Engineer, Pittsburg, Pa.

	Dry saturated steam and 27 inches vacuum.					
Test Number.....	20	10	9	8	6	22
Steam pressure outside of throttle, pounds per square inch, per gauge.....	150.3	151.4	146.8	146.5	147.1	148.0
Vacuum at outlet of L.P. cylinder, referred to 30 inches mercurial barometer, inches.....	27.08	27.11	27.10	27.11	27.11	27.05
Superheat, degrees Fahrenheit.....	...	...	...	...	...	...
Quality of steam.....	0.999	0.999	0.999	1.000	0.999	0.999
Revolutions per minute.....	1201.0	1201.2	1199.4	1197.4	1195.6	1201.0
Load in kilowatts.....	196.95	342.73	655.98	989.53	1321 $\frac{200}{250}$	1489.4
Load in electrical horsepower.....	264.0	459.42	879.33	1326.5	1771.4	1996.5
Total weight of steam consumed per hour, lbs..	7155.0	9732.0	15074	20254	25712	28208
Pounds steam per kilowatt hour.....	36.32	28.40	22.98	20.46	19.47	18.95
Pounds steam per electrical H.P. hour.....	27.08	21.18	17.14	15.27	14.52	14.13
Load in terms of nominal full rated load.....	0.157	0.276	0.525	0.790	1.060	1.190
Deductions from the above						
Pounds steam per equivalent I.H.P. of a reciprocating engine, assuming 90 per cent. combined efficiency of engine and generator, with losses constant at all loads.....	15.89	15.08	14.14	13.39	13.14	12.93
Ditto, asuming 85 per cent. combined efficiency.	12.78	12.89	12.82	12.49	12.44	12.31

I.

FOR THE INTERBOROUGH RAPID TRANSIT CO., NEW YORK.

OCTOBER 12 TO 15, 1903.

vacuum.		75 degrees F. superheat and 27 inches vacuum.					Dry saturated steam and 28 ins. vacuum.			75 degrees F. superheat and 28 inches vacuum.			
23	24	19	16	15	14	12	21	7	5	18	17	13	11
144.5	141.8	151.8	151.9	151.0	147.7	146.3	151.0	146.8	146.1	151.8	150.8	147.6	146.0
27.05	26.79	27.15	27.07	27.15	27.10	27.10	28.05	28.10	28.08	28.05	28.05	28.10	28.10
...	...	76.6	77.2	77.0	76.15	76.0	...	...	...	75.5	77.4	76.5	78.25
0.999	0.999	...	...	...	...	...	0.999	0.999	1.000	...	...	...	...
1200.0	1197.4	1201.0	1212.9	1209.0	1205.1	1200.6	1198.0	1200.6	1197.4	1217.0	1214.4	1203.8	1199.4
1713.5	198.89	191.0	333.55	664.67	986.23	1293.9	334.78	972.0	1363$\frac{9}{10}$	198.4	333.15	977.64	1274.2
2297.1	2666.0	256.0	447.1	891.0	1322$\frac{1}{25}$	1734.9	448 74	1303.0	1828.3	266.1	446.6	1310.5	1708.0
33036	40547	6734.0	9170.0	14181	19108	23903	9295.0	19334	25639	6300.0	8420.0	18180	22504
19.28	20.39	35.25	27.58	21.33	19.39	18.48	27.78	19.99	18.79	31.76	25.39	18.59	17.66
14.38	15.21	26.30	20.51	15.90	14.45	13.78	20.71	14.91	14.02	23.68	18.86	13.87	13.17
1.370	1.590	0.153	0.267	0.531	0.790	1.038	0.268	0.778	1.091	0.159	0.266	0.780	1.020
the above test results.													
13.30	14.21	15.22	14.48	13.16	12.66	12.44	14.64	12.99	12.73	13.93	13.30	12.15	11.89
12.74	13.69	12.21	12.34	11.94	11.81	11.77	12.48	12.09	12.07	11.22	11.33	11.31	11.23

EFFICIENCY AND CAUSES OF INEFFICIENCY.

The ideal efficiency of heat engines as expressed by Carnot's cycle, represented in the formulae $\frac{T_1 - T_2}{T_1}$, T_1 and T_2 being initial and final absolute temperatures, conveys the general impression of a higher thermodynamic efficiency for the steam turbine, its construction and general make up being well adapted for both high steam pressures and vacuum.

Consumptions of steam as low as 15.8 pounds per kilowatt, or about 9.8 pounds per I.H.P. per hour, are said to have been recorded with a Parsons turbine when using steam at 142 pounds pressure delivered to the engine at 482 degrees Fahrenheit, which includes about 180 degrees superheat. Quite favorable economy results were also obtained during tests performed by the Bureau of Steam Engineering at the Westinghouse Machine Company's Works, Pittsburg, Pa., with a 1,000 K.W. Westinghouse-Parsons steam turbine without superheat; these tests giving an equivalent of about 13 pounds per I.H.P., when the turbine was running at its rated capacity, and 11.9 pounds when working at 50 per cent. overload, in both cases running at approximately 1,500 R.P.M., its designed speed of rotation.

The principal loss in efficiency in steam turbines is caused by leakage of certain quantities of the steam through the clearance spaces without performing work. This leakage varies with the complexity, size and power of the turbine, and is greater in proportion in smaller machines than in those of large power. It is more in a machine composed of a number of discs arranged in several stages than in a turbine of fewer parts, being least in the single wheel turbine.

Another and very material cause of loss in the efficiency is fluid friction on the revolving parts, the amount of which varies in different types of turbines. Due to the leakage, etc., the efficiency in the blades of multiple-expansion and action turbines is considered not to exceed 80 per cent., and taking the loss caused by mechanical inefficiency at about 5 per cent., the resultant capacity of the turbine, or its efficiency as a machine to convert kinetic energy into mechanical work, actually delivered to the

shaft will be about 75 per cent. With a theoretical steam consumption of 9.0 pounds per H.P., the weight of steam per effective H.P., delivered to the shaft, will then be $\frac{9.0}{.75} = 12$ pounds.

The surface friction due to the fluid contact depends largely upon whether the turbine is run condensing or non-condensing, whether with superheated steam or without, and upon the number and diameter of the revolving discs, as well as their speed of rotation. It has been found in practice that this frictional resistance is nearly proportional to the density of the steam fluid, while experiments have demonstrated this resistance to increase in as high a ratio as the fifth power of the revolutions and the third power of the diameter of the parts revolving. The DeLaval turbine, with its very high number of revolutions, and with a diameter of disc never exceeding 30 inches, illustrates the practical application of these facts. The extent to which fluid friction absorbs the power developed by a DeLaval turbine may be judged by the results obtained in tests of a 150-H.P. machine, which showed that 35 H.P. were absorbed by fluid friction when the machine was running non-condensing, and only $2\frac{1}{2}$ H.P. when connected up to a condenser of 28 inches vacuum.

The horsepower consumed by friction due to the resistance of the steam fluid could probably be determined approximately by the following formula used for calculating the horsepower absorbed by the hydraulic disc brake, and cited by Frank M. Leavitt in his paper, "Power Expended to Drive a Whitehead Torpedo," "Transactions of the American Society of Naval Architects and Marine Engineers" of 1901.

$$H.P. = \frac{R^5 V^3 N}{C}$$

in which

R = radius of disc in feet;

V = number of revolutions of discs per second;

N = number of discs;

C = a constant varying with the nature of the frictional surfaces and the viscosity of the medium in which the discs revolve.

Deterioration of efficiency, caused by purely mechanical derangements, such as undue wear on shaft bearings or occasional distortion in the alignments of reciprocating parts, does not exist, even in a small degree, in the steam turbine, when in comparison with the piston engine. The following citation, taken from the "Report of Board to Observe and Report Concerning the Efficiency of Turbine Engines," as above referred to, says:

"21. The bearings, only having to sustain the weight of the revolving drum with its accessories, are barely loaded to a pressure of more than 50 pounds per square inch against from 300 to 400 pounds in a reciprocating engine; the peripheral velocity is, however, great, amounting to about 50 feet per second against about 10 feet for battleship engines.

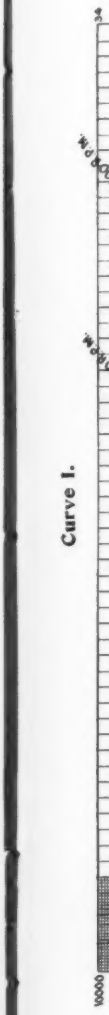
"22. * * * and are undoubtedly, both as a mechanism and a heat engine, in some cases at least, superior in efficiency when compared with the ordinary steam engine."

EFFICIENCY AT VARYING SPEEDS.

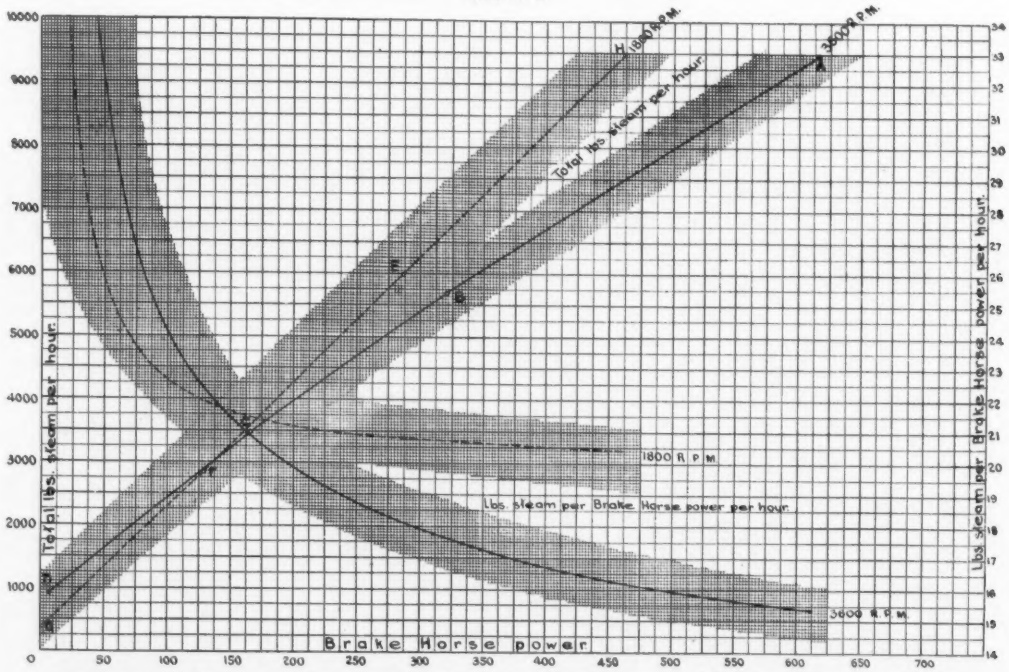
Curve I illustrates results obtained during recent tests performed with a 400-K.W. Westinghouse-Parsons turbine at 1,800 R.P.M., or one-half of the designed speed (3,600 R.P.M). For the same output of power an increase of about 25 per cent. in the steam consumption per brake horsepower per hour is shown in comparison with its economy performance at its designed speed and at its rated capacity of 400 K.W.

A very notable occurrence is the convergence of the half-speed and full-speed curves down to about 150 B.H.P., where they cross one another, after which point the consumption of steam per B.H.P. per hour at half speed, in comparison with the full-speed performance, is steadily falling off. The curves also show that the power may be much reduced with but little increase in the consumption of steam per B.H P. Results of similar tests performed with a 350-K.W. Turbo-Generator at Carlshutte, Switzerland, by Brown, Bovery & Co., are shown on Curve II.

Again, examining the steam-consumption curve per propulsive horsepower at varying speeds as plotted for the *Turbinia* during tests made by Professor J. A. Ewing and published in the "Trans-



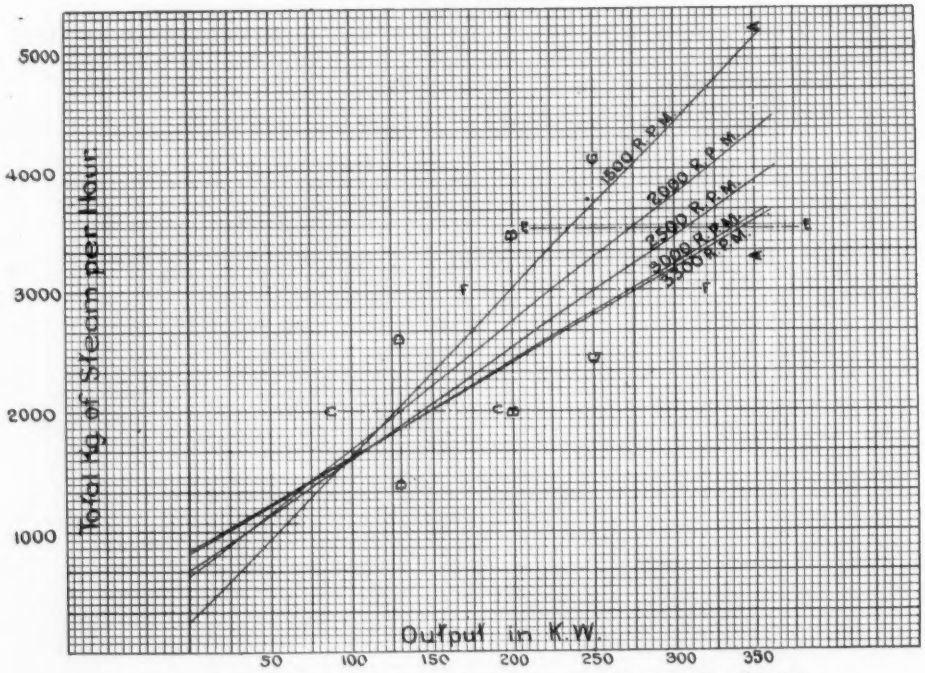
Curve I.



COMPARATIVE TESTS AT 1,800 AND 3,600 R. P. M., MADE ON 400 K. W. STEAM TURBINE, NO. 40.

Wet steam, 150 pounds gauge steam pressure; vacuum, 27 inches.
From tests 1, 2, 3, 4, 5, 6 and 13, Westinghouse Machine Co., Pittsburg, Pa.

Curve II.



350 K.W. Generator, Steam Consumption at Different Speeds.

Brown, Bovery & Co., Carlshutte, Switzerland.

actions of the Institute of Naval Architects," 1903, a considerably greater difference is apparent in the amounts of steam used per horsepower for intermediate points between maximum and minimum speeds of ship. Curve III gives the relation of steam consumed for various speeds, and shows an increase of more than 70 per cent. per P.H.P. for 16 knots over that required at 32 knots. Assuming the same slip of the propellers, the speed reduction in the turbine is in the same ratio as above for the 400-K.W. machine, but the P.H.P. required at 16 knots is only about one-fifth of that needed for 32 knots. Steam consumption per horsepower always increases rapidly with a decrease in power. This, together with the natural reduction in the economy of a turbine when run at slower speeds than those for which designed, accounts fully for the difference.

Recent investigations performed under trial with the original *Turbinia*, published in the same Transactions, showed most significantly the value of an increase in the propeller efficiency and the great improvements in general economy results in consequence thereof, even though considerable sacrifice in the dynamic efficiency of the turbines may result by reducing the speed of rotation.

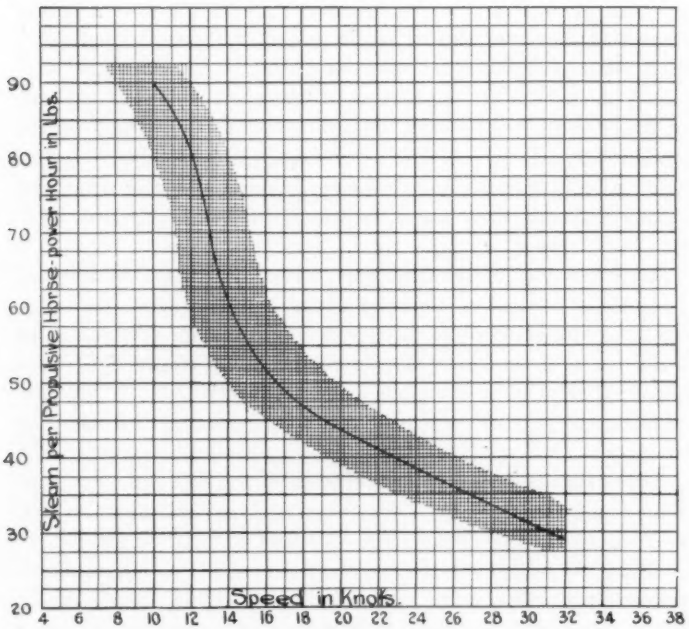
These results were obtained principally, it is inferred, by a complete change in the propeller arrangement, substituting on the *Turbinia* three single propellers, 28 inches diameter and 28 inches pitch, for the multiple screws, nine in number, of 18 inches diameter and 24 inches pitch, placed on three shafts, as previously fitted. An additional speed of 2 knots was secured on the same consumption of steam, the propulsive horsepower having increased some 23 per cent. and the slip of the screws having decreased about 10 per cent. for a speed of 21 knots.

Assuming that the propulsive horsepower (P.H.P.) = brake horsepower × propeller efficiency, it is apparent this efficiency enters very considerably as a factor in the production of a maximum P.H.P. Variations in this efficiency for a change in the revolutions, with less disturbance from cavitation and interference when in comparison with multiple screws, are no doubt responsible for the very great difference in the speed for the same

Brown, Boveri & Co., Carlsruhe, Switzerland.

steam consumption in these recent trials. It therefore appears to be of utmost importance to compromise on the rotative speeds of turbine and propeller with a view to obtain the best combined efficiency of the two.

Curve III.



[STEAM CONSUMPTION PER PROPULSIVE HORSEPOWER HOUR AT VARIOUS SPEEDS.—S. S. "TURBINIA."

The propulsive or effective horsepower may be ascertained by tank experiments, and is equal to $\frac{R \times V}{550}$, in which R is resistance in pounds as deduced by experiments on the model, and V is the speed in feet per second. The ratio between this propulsive horsepower and the indicated horsepower is between .5 and .6 and averages .57 for well designed reciprocating engines when propellers give maximum efficiency.

REVERSAL OF MOTION.

The reversal of motion from ahead to back in the reciprocating engine is performed entirely by and within the same cylinders, from the same steam pipe and by the same pistons, valves and their gear. In the steam turbine, however, as now made, a similar operation can only be reached by the complete separation of all the parts through which the reverse motion is transmitted to the shaft, as well as a separate arrangement of steam connections.

The arrangement used in turbine installations of the Parsons system consists of a turbine built to revolve in an opposite direction, placed on the same shaft, either in the exhaust cavity of the regular ahead-going turbine or as a separate motor outside. This arrangement probably necessitates additional space or entails a certain loss due to fan action and fluid friction caused by the backing motor rotating simultaneously with the ahead-going one. This loss, however, is brought down to a minimum when the reverse turbine is placed inside the casing of the ahead-going turbine, because the rotation takes place in a partial vacuum.

The system adopted in the Curtis marine steam turbine consists in an arrangement of reversing vanes placed on the same drum which imparts ahead motion, but outside of the rims containing the ahead vanes. The backing discs are placed in the low-pressure stage, in which they are encased. A separate steam pipe leads to this part of the casing, and the steam is admitted by a separate valve.

In the Westinghouse-Parsons marine reversing turbine, an impulse wheel, with a set of diverging steam nozzles, is attached to the main ahead driving drum, by means of which impulse wheel the motion is reversed. A separate steam-pipe connection is also necessary with this arrangement, but the exhaust is in common.

The reverse motion in a Rateau turbine is procured in a way very much the same as that described above, namely, by the application of an impulse turbine wheel of opposite vane action to that of the ahead vanes.

It is evident that only a fraction of the economy is secured with this arrangement when backing to what is had when going

ahead, both dynamic and thermal elements being altogether thrown out of harmony as a result of the discrepancy in the velocities of the steam with relation to the wheel.

PRINCIPLES OF ACTION.

The principal difference between a reciprocating engine and the steam turbine exists in the utilization of the potential or static heat energy of the steam. In the former this energy is converted into force by expanding back of a piston, while in the latter it is converted into kinetic energy by the velocity developed during its expansion from a higher to a lower pressure, the expansion taking place through some mechanical device in form of nozzles or suitably arranged vanes. The different means by which this expansion is accomplished and the manner in which the energy is absorbed has given rise to a number of different designs of steam turbines, which may be classified under the following heads:

1. Single-action Impulse Turbines.
2. Multiple-action Impulse Turbines.
3. Combined Action-Reaction Turbines.

In the first class the expansion of the steam takes place wholly in a distributor or nozzle, after which it issues in the form of a well defined stream or jet at a very great velocity upon vanes placed on a revolving disc which absorbs, in one stage, the greater part of the energy. To this class belongs the DeLaval steam turbine, exemplifying the problem in its simplest and most fundamental form. The peripheral speed of the disc, which, in these machines, has to be about one-half of the velocity of the issuing steam jet to attain maximum efficiency, becomes very high, and, in order to secure a practical speed of transmission, must be reduced to reasonable limits by the introduction of speed gears.

In the second class, the expansion takes place also in nozzles of the DeLaval type, the steam issuing at a considerable velocity, but differs from the former in the division or splitting of the peripheral wheel velocity, by which the energy is absorbed in steps by a series of successively intervening discs.

To this class belong the Curtis, Rateau and Riedler-Stumph turbines. The peripheral speed of the revolving discs in this case need only be a fraction of the steam velocity for maximum efficiency, and may, therefore, be arbitrated to suit the speed of transmission.

In the third class, to which belong the Parsons, and the Westinghouse-Parsons turbines, the expansion takes place principally in the vanes, and the velocity of the steam, due to the small ratio of expansion, becomes quite moderate. A velocity ranging between 350 and 650 feet per second is the usual practice in this machine, while from 2,400 to 4,500 feet per second is invariably brought into play in turbines of the impulse type.

The steam acts here both by pressure and velocity and imparts motion to the revolving drum partly by impact due to the velocity when striking the vanes and partly by reaction, due to pressure when leaving said vanes. The peripheral speed of the revolving drum in this case should be somewhere between that due to impact and reaction, and, therefore, rather more than one-half of the steam velocity, to get maximum efficiency.

ENERGY AND STEAM VELOCITIES.

As practically all the work in the impulse turbine, and the greater part of it in the combined impulse and reaction turbine, is done by velocity rather than by pressure, it will be of interest to examine into the relative changes of this velocity for a variation in the initial and terminal pressures.

The work done by a gas (steam fluid), when expanding adiabatically, is done at the expense of its stock of internal energy, and, according to Zeuner, where such adiabatic expansion takes place in a nozzle, all the potential or heat energy in the steam is transformed into kinetic energy. By derivations shown by Peabody and Cotterill the following formula is obtained, observing a few slight transformations:

$$\frac{w^1 V^2}{2g} = \frac{n}{n-1} p_1 v_1 \left\{ 1 - \frac{v_2}{v_1} \left(\frac{v_1}{v_2} \right)^n \right\}$$

$\frac{w^1 V^2}{2g}$, in the above equation, represents the actual or kinetic

Table II.

TABLE OF STEAM VELOCITIES IN FEET PER SECOND FOR VARIOUS DROPS IN PRESSURE.

Adiabatic Expansion.

ABSOLUTE FINAL PRESSURE, POUNDS PER SQUARE INCH.

Absolute initial pressure, pounds per square inch.

	165	155	145	135	125	115	105	95	85	75	65	55	45	35	25	15	5	1
165	0	520	740	920	1070	1220	1360	1490	1620	1770	1920	2090	2260	2460	2680	2930	3400	
155		0	530	760	950	1110	1260	1400	1550	1690	1840	2020	2220	2420	2640	2900	3350	
145			0	550	780	980	1150	1300	1460	1610	1770	1940	2130	2330	2580	2880	3320	
135				0	570	820	1020	1200	1360	1520	1690	1860	2060	2270	2510	2820	3300	
125					0	590	850	1060	1240	1420	1600	1780	1980	2200	2450	2760	3270	
115						0	610	890	1100	1300	1500	1700	1900	2130	2390	2720	3240	
105							0	640	920	1160	1380	1600	1820	2050	2310	2600	3170	
95								0	680	980	1230	1460	1700	1950	2240	2570	3100	
85									0	720	1040	1320	1570	1840	2120	2470	3050	
75										0	770	1120	1410	1710	2030	2400	2950	
65											0	830	1210	1540	1900	2320	2900	
55												0	890	1330	1740	2180	2830	
45													0	950	1440	2000	2600	
35														0	1100	1740	2500	
25															0	1360	2360	3200
15																0	1940	2900
5																	0	2240
1																		0

Table III.

TABLE OF STEAM VELOCITIES IN FEET PER SECOND FOR VARIOUS DROPS IN PRESSURE.

Adiabatic Expansion.

ABSOLUTE FINAL PRESSURE, POUNDS PER SQUARE INCH.

Absolute initial pressure, pounds per square inch.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0.5
15	0	495	715	888	1045	1195	1340	1480	1625	1775	1933	2105	2306	2555	2910	3210
14		0	511	736	920	1085	1245	1395	1547	1707	1866	2046	2252	2505	2863	3165
13			0	530	766	958	1135	1297	1460	1625	1798	1980	2193	2451	2820	3122
12				0	558	795	1001	1182	1360	1534	1716	1905	2128	2395	2775	3078
11					0	580	841	1050	1246	1435	1630	1828	2057	2330	2712	3030
10						0	609	876	1103	1313	1520	1735	1970	2260	2650	2970
9							0	629	920	1163	1395	1623	1878	2172	2580	2910
8								0	676	982	1245	1500	1770	2082	2505	2842
7									0	722	1053	1344	1640	1973	2410	2762
6										0	788	1145	1482	1844	2320	2673
5											0	865	1280	1685	2181	2564
4												0	976	1470	2020	2430
3													0	1130	1790	2240
2														0	1465	1990
1															0	1445
0.5																0

energy acquired by a weight w^1 moving at a certain velocity V. By making $w^1 = 1$, the kinetic energy corresponding to one pound is obtained, V being the velocity in feet per second and g the acceleration due to gravity, or 32.16 feet per second.

If the above equation is solved with reference to the velocity, then

$$V = \sqrt{2 g p_1 v_1 \times 144 \left\{ 1 - \frac{v_2}{v_1} \left(\frac{v_1}{v_2} \right)^n \right\}}, \quad . \quad . \quad (1)$$

which gives the velocity in feet per second when steam expands adiabatically in a nozzle, or other well defined device, from an absolute pressure p_1 to an absolute pressure p_2.

In formula (1), n, for adiabatic expansion, varies and depends on the dryness fraction of the steam, which in each individual case must be determined separately, and is here assumed to equal 1.135, the steam being considered initially dry.

In the above formula (1):

p_1 = initial pressure in pounds per square inch.

v_1 = volume of 1 pound of steam at p_1.

v_2 = volume of 1 pound of steam at p_2.

Analyzing the above formula, it is clear that the value of V depends both upon $\frac{v_2}{v_1}$, the "ratio of expansion," and upon n, the dryness fraction, and the greater said "ratio of expansion" is, the greater is the velocity.

In tables II and III appended, it will be noticed, the velocity increases rapidly with a decrease of terminal pressures and becomes greater for the same drop, the nearer the approach towards the vacuum line is continued. It is also apparent from the above tables that, with the same initial and terminal pressure relation, the kinetic energy per pound of steam at the end of each drop on the curve varies within comparatively small limits.

Thus with:

$\frac{p_1}{p_2} = \frac{105}{35} = 3$; $V = 2050$; H.P. per lb. of steam per hr. = 0.033;

$\frac{p_1}{p_2} = \frac{15}{5} = 3$; $V = 1933$; H.P. per lb. of steam per hr. = 0.0294;

$\frac{p_1}{p_2} = \frac{3}{1} = 3$; $V = 1790$; H.P. per lb. of steam per hr. = 0.025;

which proves the necessity for a comparatively much greater difference between these pressures for an equal amount of energy when ascending on the curve of pressures than it does when descending. This is one of the reasons why a very good vacuum is extremely desirable in connection with steam turbines, especially as such vacuum may be used in the turbine without correspondingly bad effects from condensation and increased friction, which, in a reciprocating engine, necessarily follow the enlargement of the cylinders.

THE DE LAVAL NOZZLE.

Attention has already been drawn to the relation existing between "velocity" and "ratio of expansion," the importance of which may best be understood by a diagram showing the action of the steam in a De Laval expanding nozzle. The completeness of the expansion in this nozzle is easily perceived when it is mentioned that in a nozzle only 3 inches long, with a steam inlet of $\frac{1}{8}$ inch and an orifice $\frac{3}{8}$-inch diameter, the steam may be expanded from 165 pounds absolute to 3 pounds absolute, or at a rate of $\frac{118}{2.72} = 43.4$ expansions, all within a length of 3 inches.

By laying out the curve for adiabatic expansion of saturated steam this sudden fall of pressure near to and in the throat of the nozzle may be accounted for, also the further drop along the diverging part of the nozzle.

Assume the initial pressure to be 250 pounds by gauge with the steam initially dry and that expansion takes place according to $pv^{1.135} =$ Constant, then the curve, Fig. D, representing this condition, will nearly answer to what actually occurs during expansion of the steam in the nozzle. The pressure at the most contracted part of the throat, with an initial pressure of 265 pounds absolute at the inlet, will be about 153 pounds absolute, according to $\frac{p_1}{p_2} = .58$ in Fig. A. Theory as well as experiments have proved that a maximum steam flow occurs when the above relation of pressures exists, from which $p_2 = .58 \times p_1 = 153$ pounds absolute is derived. The terminal pressure at the orifice of the

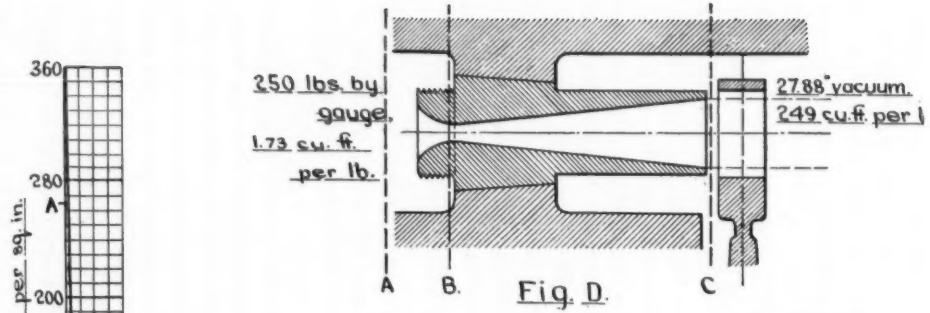
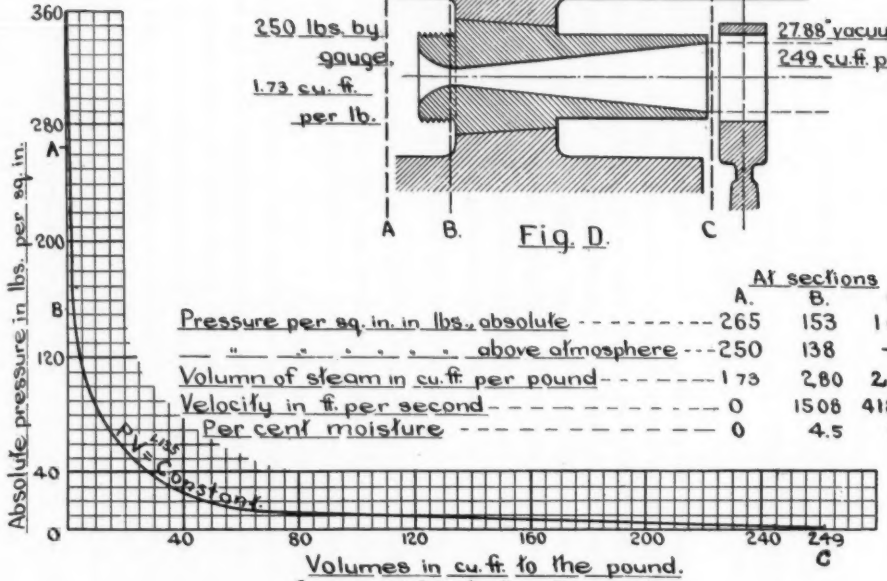


Fig. D.

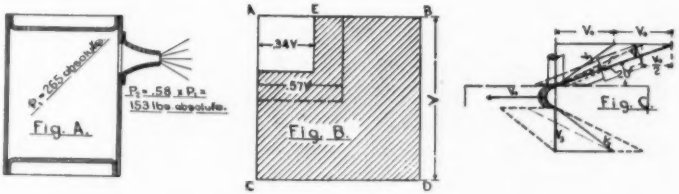
	At sections A.	B.	C
Pressure per sq. in. in lbs., absolute	265	153	1 00
" " " " " above atmosphere	250	138	–
Volumn of steam in cu. ft. per pound	1 73	2.80	2.49
Velocity in ft. per second	0	1508	4180
Per cent moisture	0	4.5	26



Curve of Adiabatic Expansion.

NOTE.—Due to error in transposition of curve, the pressure and volume scales do not agree at intermediate points.

nozzle depends upon the relation between inlet and outlet areas as well as the length of the nozzle itself. When figuring the velocity according to the formulæ given above it is important to bear in mind that the actual volume of the steam becomes con-



siderably decreased after expansion, due to the moisture contained. The percentage of this moisture may be figured from the following formulæ, given by Ewing in his treatise on heat engines:

$$q = \frac{T}{L}\left(\frac{q_1 L_1}{T_1} + \log_e \frac{T_1}{T}\right).$$

For conditions given in Fig. D,

$$q = \frac{563}{1043}\left(\frac{1 \times 826}{866} + \log_e \frac{866}{563}\right) = .74.$$

This means that by the time the pressure has fallen to 1 pound absolute, just .26 of the originally dry steam has become condensed into water. The volume occupied by the steam is thus $= qv =$ $335 \times .74 = 249$ cubic feet per pound, and the velocity at the orifice according to the formulæ given above will be 4,180 feet per second at the orifice of the nozzle. In the same way the moisture at section B will be found $4\frac{1}{2}$ per cent. of the total volume, and the velocity at this point about 1,508 feet per second.

Table IV gives the velocity of outflow in a DeLaval nozzle for different initial pressures under certain conditions of back pressure. The kinetic energy and the equivalent H.P. per pound of steam is also given.

Table IV.

THE VELOCITY OF OUTFLOW AND THE WORKING CAPACITY OF DRY SATURATED STEAM.*

Initial steam pressure, lbs. per sq. in., absolute.	Counter-pressure, 1 atmosphere.			Counter-pressure, 2.4 lbs. per sq. in. absolute, corresponding to 25 ins. vacuum.			Counter-pressure, .93 lbs. per sq. in. absolute, corresponding to 28 ins. vacuum.		
	Velocity of outflow of steam, ft. per sec.	Kinetic energy, ft.-lb. per sec.	H.P. of 550 ft.-lb. per second.	Velocity of outflow of steam, ft. per sec.	Kinetic energy, ft.-lb. per sec.	H.P. of 550 ft.-lb. per second.	Velocity of outflow of steam, ft. per sec.	Kinetic energy, ft.-lb. per sec.	H.P. of 550 ft.-lb. per second.
		Per lb. of steam per hr.			Per lb. of steam per hr.			Per lb. of steam per hr.	
60	2,421	25.29	0.046	3,320	47.57	0.087	3,680	58.44	0.106
80	2,595	29.06	0.053	3,423	50.56	0.092	3,793	62.08	0.113
100	2,717	31.86	0.058	3,520	53.47	0.097	3,871	64.66	0.118
120	2,822	34.37	0.062	3,596	55.80	0.101	3,940	66.99	0.122
140	2,913	36.62	0.066	3,661	57.84	0.105	3,999	69.01	0.125
160	2,992	38.63	0.070	3,718	59.65	0.108	4,045	70.61	0.128
180	3,058	40.35	0.073	3,764	61.14	0.111	4,091	72.22	0.131
200	3,115	41.87	0.076	3,810	62.64	0.114	4,127	73.50	0.134
220	3,166	43.26	0.079	3,852	64.03	0.116	4,159	74.64	0.136
280	3,294	46.83	0.085	3,962	67.74	0.123	4,229	77.18	0.140
265	3,313	47.38	0.0861	4,013	69.56	0.126	4.280	79.2	0.144

* Reprinted (except line 265, for velocities of which $n = 1.135$ is assumed) from paper read by Mr. Konrad Anderson, Institution of Engineers and Shipbuilders of Scotland.

SINGLE-ACTION IMPULSE TURBINES.

Turbines under this head consist fundamentally of a rotating disc attached to a shaft and a steam-distributing nozzle through which the steam issues against the vanes of the wheel at a velocity, V, as found above. The kinetic energy being proportional to the square of the velocity, it may be diagrammatically represented by square $ABCD$ in Figure B, AB being representative of the entering velocity, V. If the absolute velocity of the steam after its passage through the wheel be represented by AE, then the kinetic energy absorbed by the wheel will be proportional to $AB^2 - AE^2$, or the shaded part, the unshaded portion indicating

the amount of energy lost, due to the velocity still retained by the departing steam, and the efficiency, neglecting frictional losses, will be $\frac{AB^2 - AE^2}{AB^2}$.

If, in Figure C, V_0 represents the perimetral velocity of the revolving wheel, and

V = absolute velocity of steam entering vanes;
V_1 = relative velocity of steam entering vanes;
V_2 = relative velocity of steam leaving vanes;
V_3 = absolute velocity of steam leaving vanes;

then, in order to arrive at a minimum value for V_3, V_0 should be made about 47 per cent. of V, and the nozzle should be given an incline towards the wheel face of 20 degrees. The relative velocity of the steam entering and leaving the wheel remains unaltered, due to the vane space being parallel, and the volume, on that account, constant.

From the triangle of velocities, the effect of a decrease in the peripheral velocity V_0, caused by a reduction in the speed of revolution, will at once be apparent. With $V_0 = \frac{47}{100} V$, V_3 becomes a minimum or equal to $\frac{34}{100} V$, at which the efficiency is a maximum, or equals $\frac{V^2 - \left(\frac{34}{100} V\right)^2}{V^2} = 88$ per cent. If the speed of rotation is reduced one-half, then V_0 becomes $\frac{V_0}{2}$ and the absolute velocity at which the steam leaves the wheel will be V_2 with a corresponding efficiency $\frac{V^2 - \left\{\left(1.7 \times \frac{34}{100}\right) V\right\}^2}{V^2} = \frac{1 - .33}{1} = 67$ per cent., indicated by the dotted belt in Fig. B.

A single impulse wheel is never allowed to run at its theoretical velocity when the steam velocity exceeds 3,500 feet per second, on account of the excessive strains on the material caused by centrifugal forces. The magnitude of this force may be understood when it is mentioned that a bucket weighing

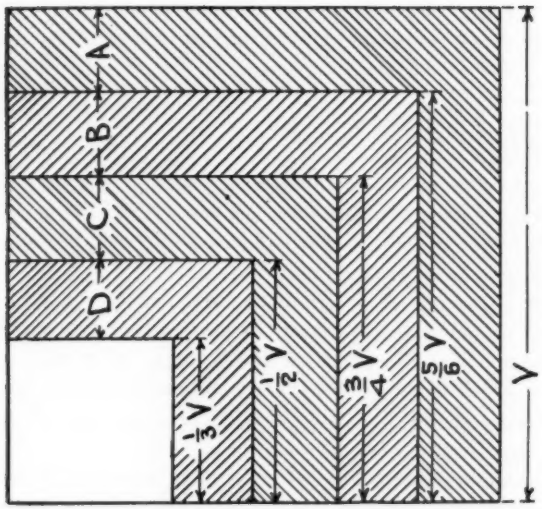

A
B
C
D
1/3 V
1/2 V
3/4 V
5/6 V
V

Fig. E.

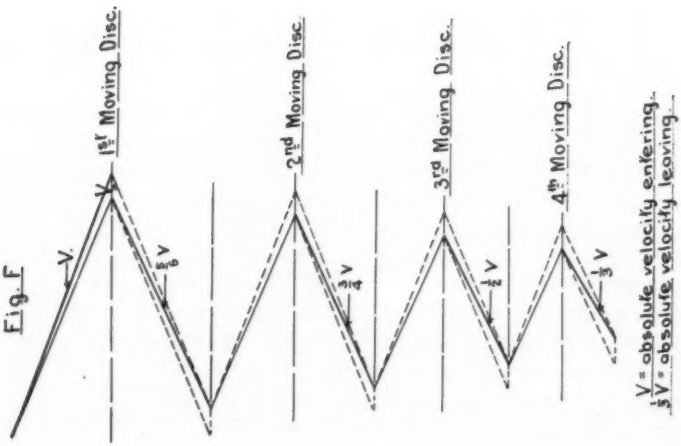


Fig. F
V
1st Moving Disc.
5/6 V
2nd Moving Disc.
3/4 V
3rd Moving Disc.
1/2 V
4th Moving Disc.
1/3 V
V = obsolute velocity entering.
1/3 V = obsolute velocity leaving.

about $\frac{5}{8}$ ounce exerts a centrifugal force of nearly 1,500 pounds, the wheel having a mean diameter of 30 inches revolving at 10,600 turns per minute.

The theoretical H.P. per hour per pound of steam, assuming a velocity $V = 4000$ feet per second with a peripheral wheel velocity such as to make $V_0 = 1800$ feet per second is,

$$\text{H.P.} \times 550 \times 3600 = \frac{4000^2 - 1800^2}{2g} \cdot \quad \text{H.P.} = \frac{14{,}040{,}000}{550 \times 3600 \times 64.32} = .1;$$

and the steam consumption per hour per theoretical horsepower

$$\frac{2g \times 550 \times 2600}{4000^2 - 1800^2} = 10 \text{ pounds.}$$

MULTIPLE-ACTION IMPULSE TURBINE.

Turbines of this class consist of a plurality of movable and stationary discs, arranged in one or more stages, each of which is acted on by a distributing steam nozzle, or sometimes by a series of such nozzles. The movable discs are attached to the revolving shaft, while the stationary ones are held in the casing.

A diagrammatical representation of energy absorbed by any one individual wheel in a separate stage is illustrated in Fig. E. A combination speed triangle diagram for the determination of the initial and terminal absolute velocities is shown in Fig. F. From the first set of nozzles, assumed to be of the DeLaval diverging type, a jet of steam issues at a velocity V on the first set of movable vanes, which have a peripheral velocity V_0, such as to give to the shaft any speed considered practical for the purpose of direct transmission.

Referring to Fig. F, it is assumed the vane spaces are parallel and the passing volumes constant, and, therefore, the relative velocity of the entering and leaving steam are practically constant for each disc. In practice a slight increase between each succeeding line of vanes is usually provided for, the increase in velocity thereby gained making up for the loss due to friction.

If V is the steam velocity of the jet in feet per second after its issue from the nozzle, and if V_0 is the velocity of the wheel periphery in feet per second, which may be assumed $\frac{1}{12} V$, then

the absolute velocities after passage through each disk will be as shown in Fig. F, and will be for this special case approximately, $\frac{5}{6}V$, $\frac{3}{4}V$, $\frac{1}{2}V$ and $\frac{1}{3}V$. The energy abstracted by the first set of movable discs is propotional to $V^2 - \frac{5}{6}V^2$, represented by the shaded portion A, in Fig. E. Similarly the energy abstracted by the second set is proportional to, $\left(\frac{5}{6}V\right)^2 - \left(\frac{3}{4}V\right)^2$, represented by B, and so forth, until the last line of moveable vanes has been reached. The total energy abstracted by all wheels together, being the sum of each individual portion, may be expressed direct by taking the difference between the squares of the initial and final absolute velocities, and its efficiency, neglecting losses due to friction as before,

$$\left[V^2 - \left(\frac{1}{3}V\right)^2\right] \div V^2 = \frac{8}{9} = .88 \text{ per cent.},$$

which is identically the same as in the single wheel.

By splitting and successively abstracting energy, as shown above, it is possible to give to the revolving drum a reasonable speed, thereby obviating all outside mechanical devices that would otherwise be necessary for the purpose of speed reduction. The work lost, due to fluid friction, leakage and eddies, in a multiple arrangement of discs of the kind described will, however, in all probability, be at least equal to any loss caused by the frictional resistances set up by gear wheels necessarily provided for in single-disc turbines, which, if structural conditions would permit, perhaps would show a superior efficiency in comparison with more complex machines.

Attention has previously been drawn to the necessity for keeping the ratio of expansion within certain limits to obtain a certain steam velocity. Obviously, then, when high initial steam pressures are used and the turbine is worked in conjunction with a high degree of vacuum, expansion of the steam, in one stage or through one series of nozzles, would result in quite an excessive steam velocity, unsuitable for purposes where a reasonable

wheel velocity is desirable without the intervention of speed-gears. For this reason principally, but also on account of the wear and tear on the vanes, caused by the excessive impact of the jet, when issuing at a very high velocity, the expansion is divided up among several stages, each of which is usually arranged to handle equal parts of the total power of the steam.

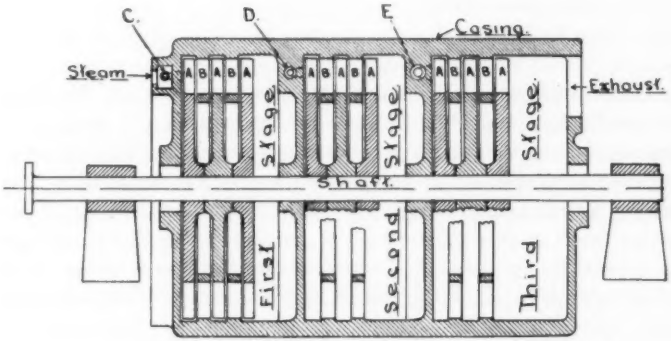


Fig. G.

Fig. G represents in a crude form a skeleton outline view of a three-stage multiple-action turbine intended for high initial pressures. There are three moving discs and two stationary discs to each stage. *A* are vanes attached to the moving discs. *B* are vanes attached to stationary discs. *C*, *D*, *E* are expanding nozzles respectively for the first, second and third stage. The jet velocity must be the same in each series of nozzles to create the same amount of kinetic energy per pound of steam in each separate stage, and the nozzles between the various stages must therefore be proportioned with a view to obtain this result. The expansion through the turbine following approximately adiabatic lines, it will be comparatively easy, by the aid of the adiabatic curve laid out for the initial and terminal pressures especially stipulated by any pending case, to figure the quantities relating to the nozzle.

The quantity of steam passing through an orifice, depending on the velocity as well as on the specific volume corresponding to any particular pressure, may be found from

$$Q = \frac{V}{U}.$$

Q = quantity in cubic feet per second per square foot.
V = velocity in feet per second.
U = specific volume.

COMBINED ACTION-REACTION TURBINES.

Steam turbines of this class, and to which Parsons, Westinghouse-Parsons and Dow turbines belong, consist of a plurality of moving vanes attached to a revolving drum, each set being interspersed by stationary or guide vanes fastened to the casing. The steam is thus guided alternately by the fixed vanes to the moving vanes, each in turn abstracting a portion of the kinetic energy possessed by the steam. The expansion in these turbines takes place between each set of vanes, and not, as in the impulse tur-

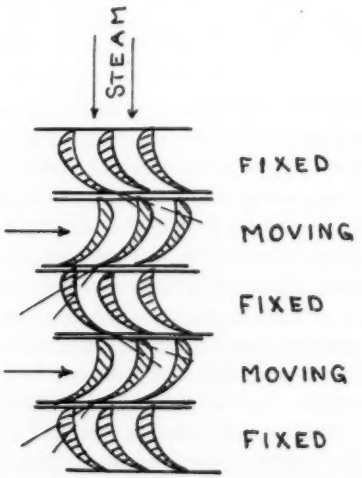


Fig. H.—FLOW OF STEAM THROUGH VANES IN PARSONS OR WESTINGHOUSE-PARSONS STEAM TURBINE.

bines, within a nozzle. The velocity is thus produced by expansion caused by a small drop in the pressure from one set of vanes to the next, arranged in such a manner that the absolute velocity leaving each set of vanes is retained through the machine at practically a uniform quantity. Fig. H shows in a general way the disposition of fixed and moving vanes of a Parsons turbine in relation to each other, the relative and absolute velocities being indicated by the diagonal lines shown across the vanes.

With reference to the velocity diagrams shown above, they must not be considered as representing actual velocities in the various turbines, but are only intended to demonstrate the approximate flow of steam through a steam turbine. The actual velocities are dependent on a number of varying conditions such as the angles of the vanes, frictional resistances, condensation, section of passages, etc., which has not been taken into consideration in the above discussion.

PARSONS AND WESTINGHOUSE-PARSONS TURBINES.

This turbine is commonly classed as a combined action and reaction turbine, the steam acting both by pressure and impulse, and is technically designated a parallel-flow, multiple-expansion turbine.

Its great field of operation has no doubt been secured as a result of proved economy in the usage of steam, as well as by its adaptability of design to produce shaft speeds suitable to a diversity of applications, both stationary and marine, together with the excellence of workmanship observed in its manufacture.

Owing to the low steam velocity aimed at, thereby necessitating the introduction of a system involving a great number of vanes, its design calls for an extension in length rather than an increase in diameter, the length depending to a large extent on the initial pressure used. In cases where comparatively higher shaft speeds are permissible, and therefore a higher steam velocity, a greater drop of pressure is utilized between each set of vanes, and therefore fewer sets suffice to accomplish the same total range of expansion, the length of the turbine being considerably reduced thereby. If a low speed of revolution is desired, with a

comparatively great drop in pressure between each succeeding set of vanes, thereby creating a higher steam velocity, then a correspondingly greater increase in the diameter is made, enabling the length of the machine, in this case also, to be reduced with certain reference to the spacing and pitch of the vanes. Expansion of the steam is wholly within the casing, and is provided for by gradually increasing the spacing as well as the length of the vanes.

When used for marine purposes, the backing turbines, being complete separate parts, will always require independent steam connections, and if placed in separate casings, making individual machines, will, besides, require a separate exhaust pipe to the condenser.

In the Westinghouse-Parsons proposed marine turbine, as shown in Plate A, a separate impulse turbine wheel, *M*, with multiple expansion vanes, movable and stationary, is connected to the shaft in the low-pressure end of the turbine. In the illustration shown all small and unessential details are omitted, thereby bringing about a clearer understanding of the more important parts.

A is the inlet for ahead motion.

B is the inlet for astern motion.

C is the exhaust outlet.

E is a pipe connecting the chamber *D* with the exhaust passage *C* in order to equalize the pressure at the two ends of the turbine.

The steam from *A* passes through the blades, in successive stages, *F*, *G* and *H*.

J, *K* and *L* are the balance pistons corresponding with the blade stages.

When going astern the steam from *B* passes through the blades *M*, which are in extent only a fraction of the blades for ahead motion, being so proportioned as to give the necessary backing power, but lacking the economy of the blades for ahead motion.

E is the thru st bearing for end adjustment of the turbine. When this thrust bearing is used, there would be a flexible

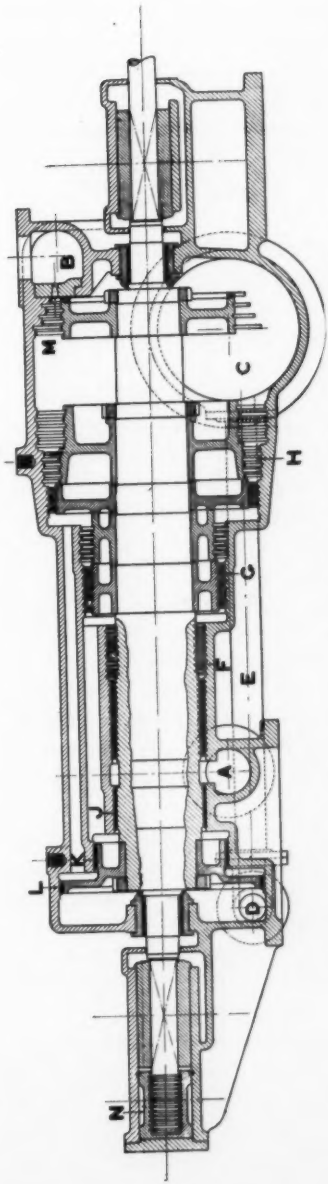


Plate A.—WESTINGHOUSE-PARSONS REVERSIBLE STEAM TURBINE, MARINE TYPE.

coupling between the turbine and the propeller shaft. If preferred, however, this thrust bearing could be omitted, the turbine being adjusted by the main thrust bearing, which is not shown by the drawing.

When used for marine installation, the total power of a Parsons turbine is usually divided on three or more shafts with the reverse turbines placed either independently or in the low-pressure end of one or more of the regular ahead turbines.

The unbalanced pressure on the vanes, which calls for the introduction of balance pistons in stationary turbine practice with the Parsons type, may be partly taken up and counteracted by the propeller thrust when going ahead, when used for marine purposes, but must, of course, be fully provided for and prevented by the introduction of an efficient thrust block on the shaft when backing motion is contemplated.

Previous illustrations in this article give steam-economy results of these turbines running both at full and varying speeds, also as installed in the *Turbinia*.

THE RATEAU TURBINE.

This type belongs to that class of turbines where the steam acts principally by impulse, and is illustrated in Plate B. The velocity of the steam, being created by expansion in a primary set of diverging nozzles, is reduced in steps by action upon a series of moving discs placed in the first stage. Between each moving disc is placed a stationary guide disc, all containing separate vanes. New velocity is given the steam by further expansion in a secondary set of nozzles (D^2), and the energy now developed in the second stage is absorbed by its series of larger sized movable discs. With respect to this arrangement it resembles that of the Curtis type. In contradistinction, however, it is to be noted, besides the expansion derived by expanding in the nozzles, that a further expansion is obtained in a high degree by gradual enlargement of the spaces between the blades, both stationary and moving, thereby creating a certain amount of new velocity and energy, which is absorbed in continuance by each succeeding set of discs.

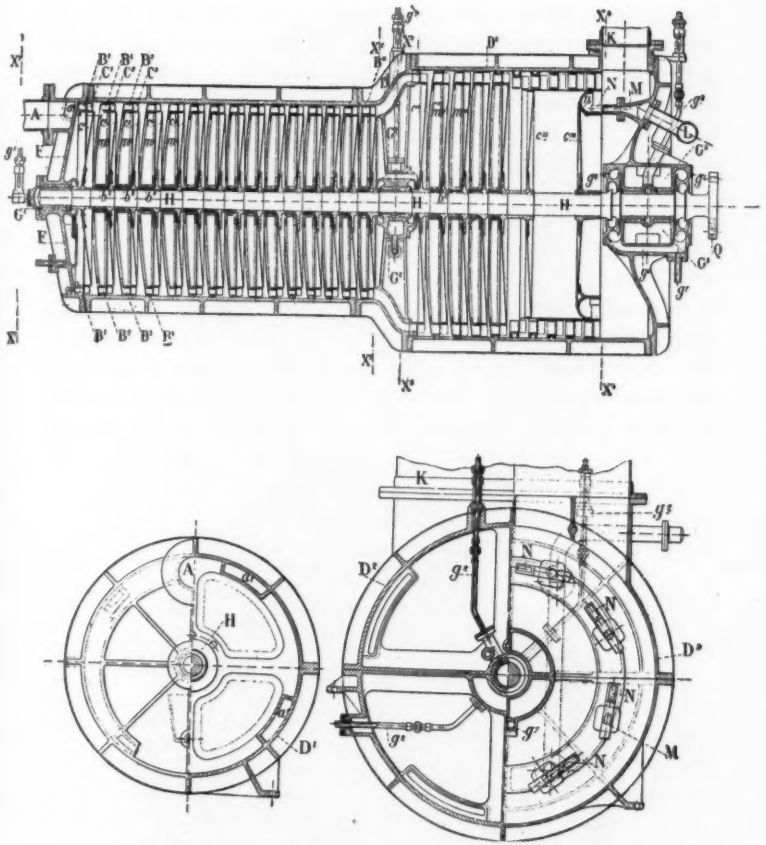


Plate B.—RATEAU REVERSIBLE STEAM TURBINE, MARINE TYPE.

The clearance spaces, by which, in turbine machinery, is usually understood an amount of free space allowed between the moving and stationary vanes both sidewise and peripheral, are here made about $\frac{1}{8}$-inch, and thus of ample proportions. The leakage between each step is greatly reduced by providing for an almost steam tight fit between the center of the guide blade diaphragms and the shaft, and further because of the small dif-

ference in pressure existing between each individual step. It may be understood readily, however, that the frictional resistances, both fluid and otherwise, are greatly increased by this mode of construction, and the apparent gain due to less leakage is outweighed by said losses which, together with the leakage, amount to a very great percentage of the total power developed.

The general construction of the Rateau turbine is well adapted for marine purposes, both because its speed of revolution may be kept within reasonable limits and because of the facility with which it may be reversed. This latter operation is accomplished as in the Westinghouse-Parsons marine turbine, by direct action from a single impulse turbine wheel placed in the exhaust end. The vanes (N) of this wheel are set in the opposite direction of the ahead-going ones. The efficiency obtained when backing is, of course, comparatively small because of the very much reduced

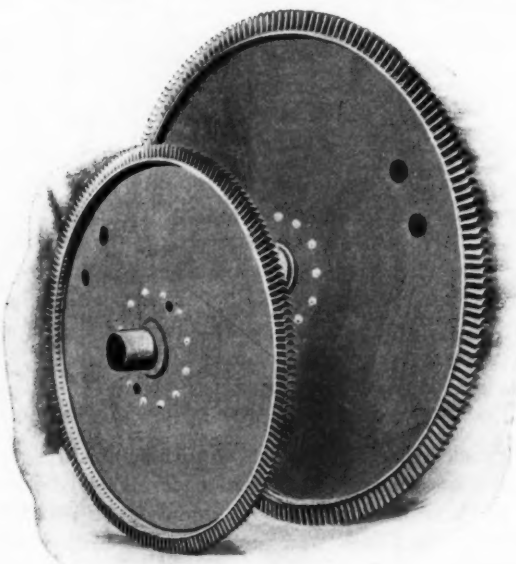


Fig. 1.—Moving Discs, Showing Vanes.

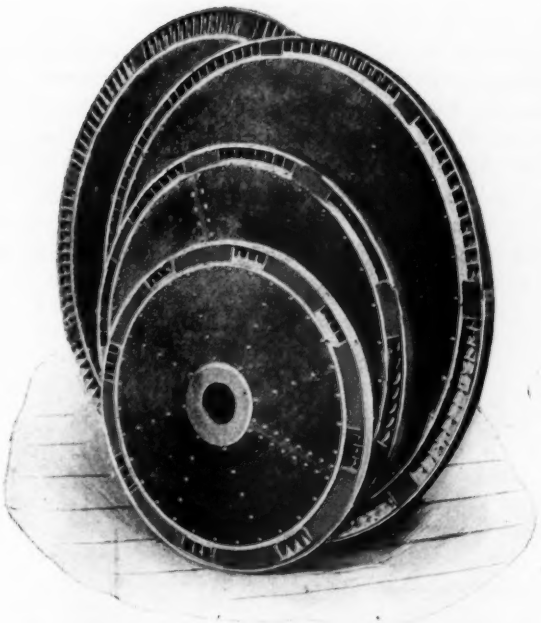


Fig. 2.—Stationary Discs, Showing Guide Vanes.

shaft speed, which must conform to a permissible speed for the propeller. No appreciable end thrust exists in this turbine, and therefore no balance pistons are required. The thrust of the propeller is compensated by a difference in pressure acting on the drum shown to the right of the cut.

In the cut, A is the steam pipe through which the steam enters to the first nozzles B^1 B^1, which direct the jet against the first vane wheel C^1 C^1. After having passed through all the cells contained in the small portion of the wheel, it enters nozzles D^2, where it further expands, giving new velocity, the energy of which is taken up by each succeeding step in the larger portion of the wheel. Fig. 1 shows the vane wheel which causes the shaft to revolve, while in Fig. 2 are shown the guide-blade diaphragms.

THE DE LAVAL STEAM TURBINE.

This turbine is of the purely impulse type, utilizing a very high initial jet velocity on one wheel with a single row of buckets. In order to secure maximum efficiency in the abstraction of kinetic energy, the wheel and shaft velocities must be extremely high, and consequently have reached speeds far beyond that permissible for direct transmission. On this account it is unsuitable for continuous driving of screw propellers direct, but in combination with other turbines, may be and is used for reversing purposes.

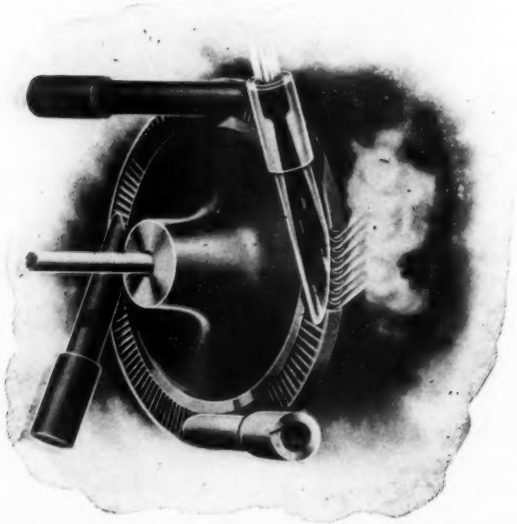


Plate C.—De Laval Steam Turbine Wheel, Four Expanding Nozzles.

Its greatest field of utility has been developed for purposes where great shaft speeds are of no special detriment, such as in connection with small electric generators, blowing machines, certain pumps, etc.

The two most distinguishing features in its makeup consist in: First, the introduction of the flexible shaft, enabling the disc

to be run at an extremely high and otherwise probably prohibitive speed of revolution; second, the diverging or expanding nozzle, without which not even an approach to the present jet velocity could have been attained. It is interesting to note that in every turbine design, excepting Parsons' and Dow's, now in successful practical operation, is incorporated the diverging nozzle. For this reason, as well as for reasons peculiar to itself, it seems justified to give to this invention a great part of the credit for the development made in modern steam turbine design.

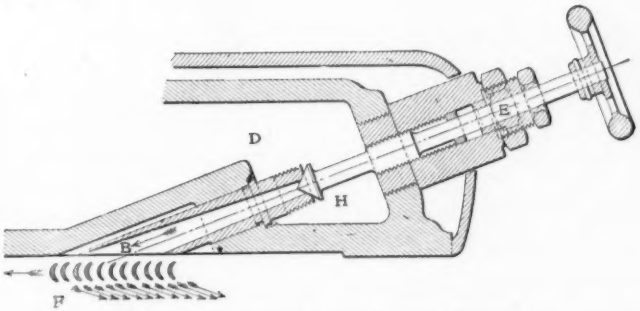


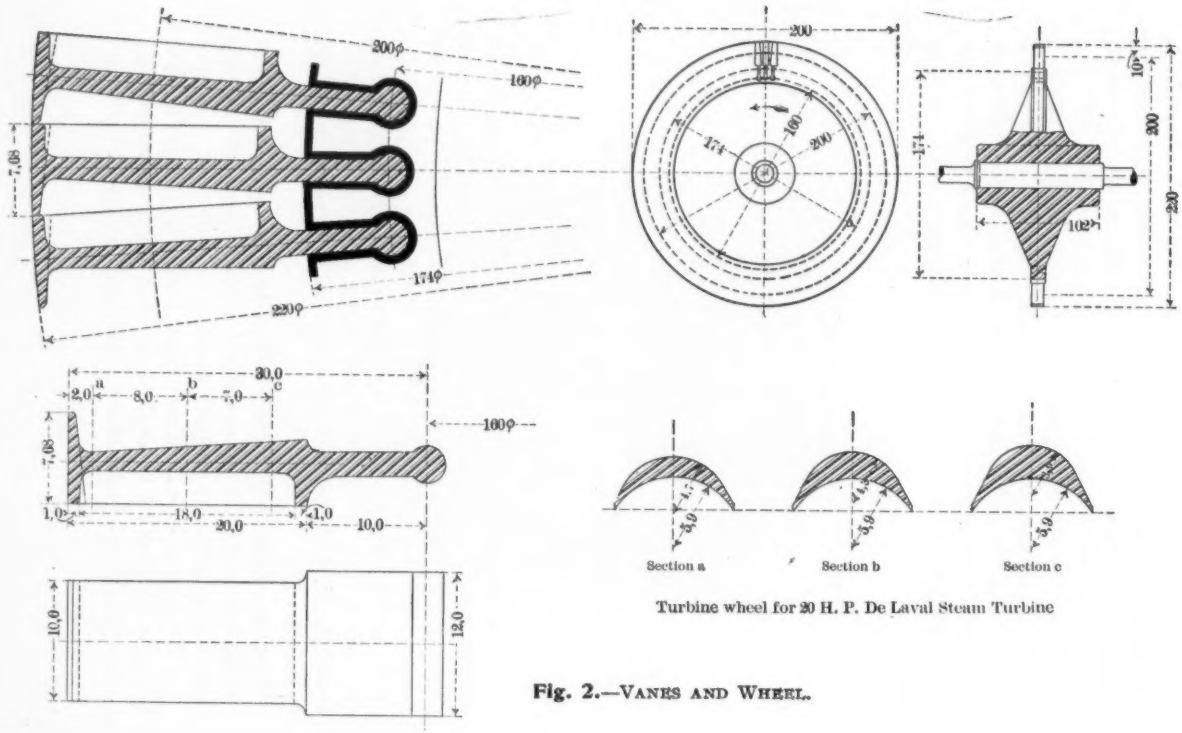
Fig. 1.—ARRANGEMENT OF STEAM NOZZLE.

A very high steam pressure, together with superheated steam, may be used to greater advantage in this turbine than in any other, and the small weight and space occupied for power developed are among its most characteristic features.

On account of the excessive stresses due to centrifugal action this turbine has not been manufactured in units of more than about 300 B. H. P., nor can it well exceed this limit with present materials.

Its high efficiency is traceable no doubt to smaller losses from leakage, as well as to the considerably reduced amount of fluid friction due to its extreme simplicity.

In the accompanying illustrations a view is given, Fig. 1, of the expanding nozzle in conjunction with a part peripheral section of the vanes. Fig. 2 shows transverse sections of the vanes.



Turbine wheel for 20 H. P. De Laval Steam Turbine

Fig. 2.—VANES AND WHEEL.

Particular notice should be taken of the manner in which the vanes are secured.

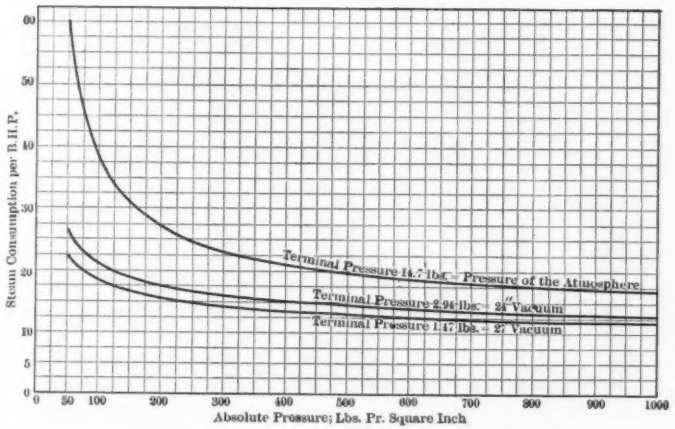


Fig. 3.—CURVE OF ACTUAL STEAM CONSUMPTION PER B.H.P., DE LAVAL STEAM TURBINE.

Fig. 3 gives actual steam-consumption curves plotted per B.H.P., and shows the relative importance of varying degrees of vacuum in comparison with an atmospheric exhaust.

A sectional view, clearly showing the turbine wheel as well as the spiral gearing, is given in Fig. 4. It is interesting to observe that the space occupied by the gear-wheel casing far exceeds that of the turbine casing itself.

RIEDLER-STUMPF TURBINES.

Being of comparatively recent design and manufacture, this turbine probably has not been subjected to the many and rigid trials of those previously mentioned. The tests that have been made, however, are said to show gratifying results especially with regard to steam consumption.

It is an impulse turbine, which, with regard to its utilization of energy, is made either with single or multiple action. In the simplest form, and when made in small units, it consists of a shaft with a revolving disc, upon the periphery of which pockets

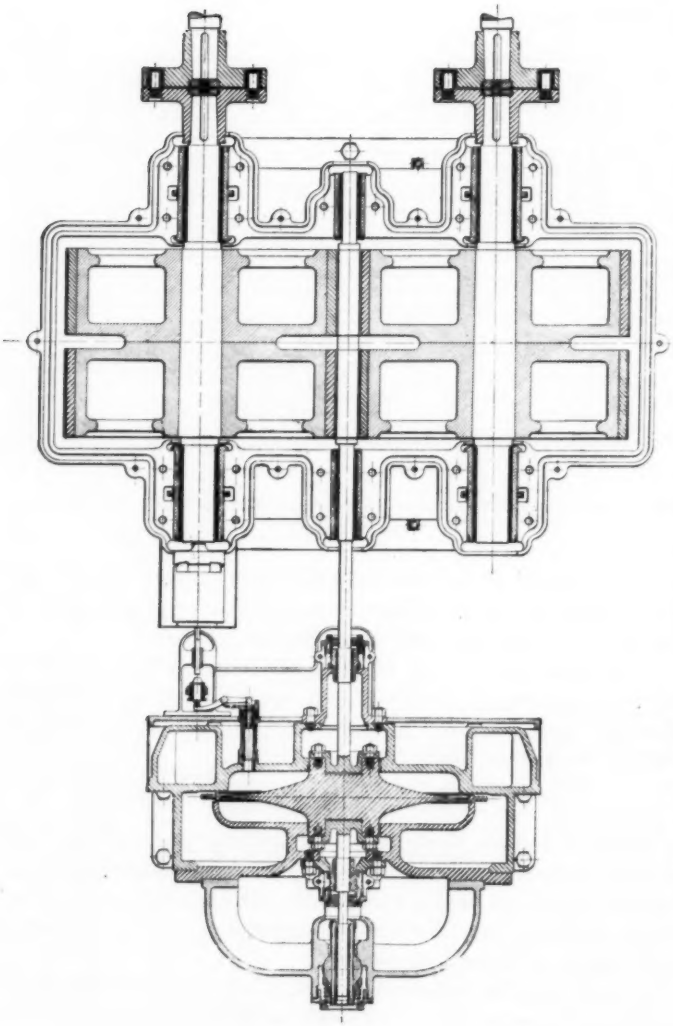
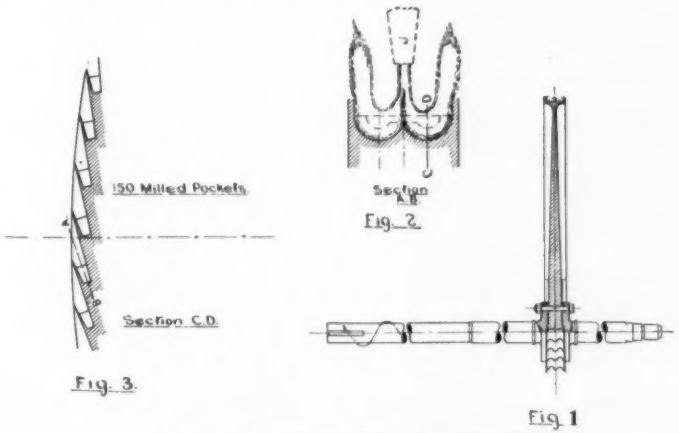


Fig. 4.—De Laval Steam Turbine, Showing Wheel and Spiral Gears in Section.

are cut forming vanes, similar in action to those on a Pelton wheel, The steam issuing from the jet (*J*), Fig. 2, thus impinges on a line square to the face of the wheel, and not as in the De Laval turbine, where it enters on the one side of the disc, leaving on the other. A possibly more complete transfer of energy may be accomplished by this application, the novelty of a Pelton bucket in combination with a De Laval expanding nozzle being apparently one of the features in this steam turbine. Fig. 1 illus-



VANES OF RIEDLER-STUMPF TURBINE.

trates such a turbine without pressure stages or with single utilization of the impact velocity. Figs. 2 and 3 show the vanes in different sections, while Figs. 4 and 5 illustrate an arrangement of expanding nozzles together with the deflecting guard (*C*), the purpose of which is to convey the steam leaving the first set of vanes (*e*) to the second set (*r*). This deflecting guard, *C*, being of equal sectional area throughout its length, does not, it seems, allow for the usual increase in steam velocity as commonly provided for in the arrangement of moving and stationary vanes in Parsons and Curtis turbines. The guard as arranged becomes of much greater length, and therefore offers more frictional resistance to the fluid than does the much shorter and

more direct guide vanes used in either of the machines mentioned. Neither is there an equal chance of obtaining increased velocity by successive expansion, while extra condensation takes place in the more exposed surfaces.

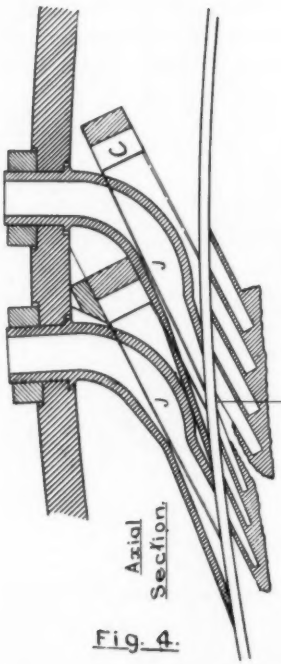


Fig. 4.

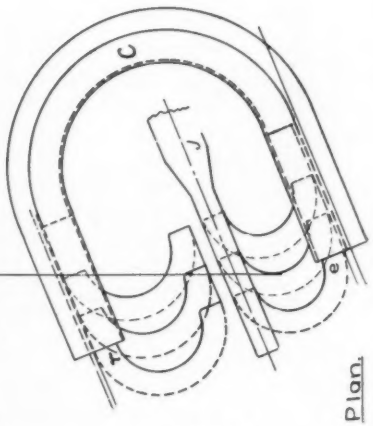


Fig. 5.

NOZZLES AND VANES, RIEDLER-STUMPF TURBINE.

The kinetic energy in this turbine, as in the Curtis or Rateau, is taken out in steps by the device above illustrated, thereby enabling the wheel and shaft velocity to be arranged for direct transmission at a reasonable speed. By continued expansion of the steam in additional stages new velocity is given the steam, creating energy which in succession may be absorbed by other

wheels. A multiple-stage machine, with a plural utilization of energy to meet this condition is shown in Plate D.

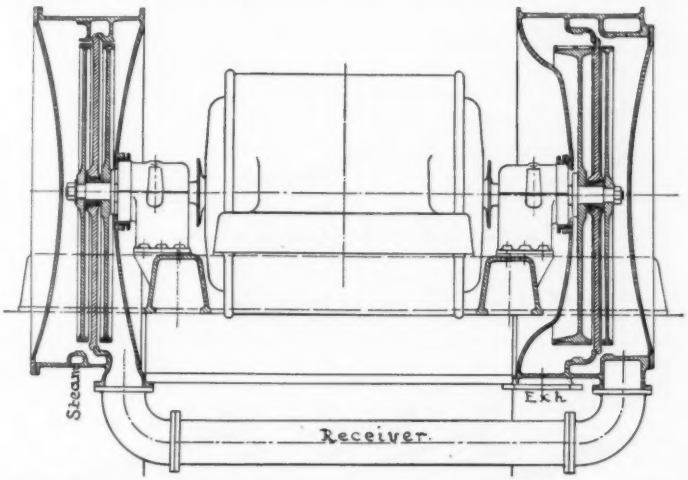


Plate D.—DOUBLE-VANE, 4-STAGE, RIEDLER-STUMPF STEAM TURBINE.

THE CURTIS STEAM TURBINE.

The Curtis turbine is of the multiple-action impulse type, and has features in common with both the Parsons and the DeLaval turbines; somewhat more of the latter, however, than of the former. Its distinguishing characteristics lie principally in the action of the steam upon a multiple serial arrangement of discs alternately, movable and stationary, in a combination of stages. By these means it is possible to secure for the revolving parts speeds low enough not to require special gear, but which may meet the average demands as now presented in practice.

The general arrangement of the vanes, and, relatively, of the discs and nozzles, are shown in Fig. 1.

The nozzles are of the diverging DeLaval type, and are arranged in clusters at interval spaces along the periphery of the first moving disc. The steam action may be compounded into any number of stages, each one of which contains its separate

number of discs and steam nozzles. The number of stages and the arithmetical extent of each series of discs in the stage are governed by the degree of expansion desired or by the peripheral

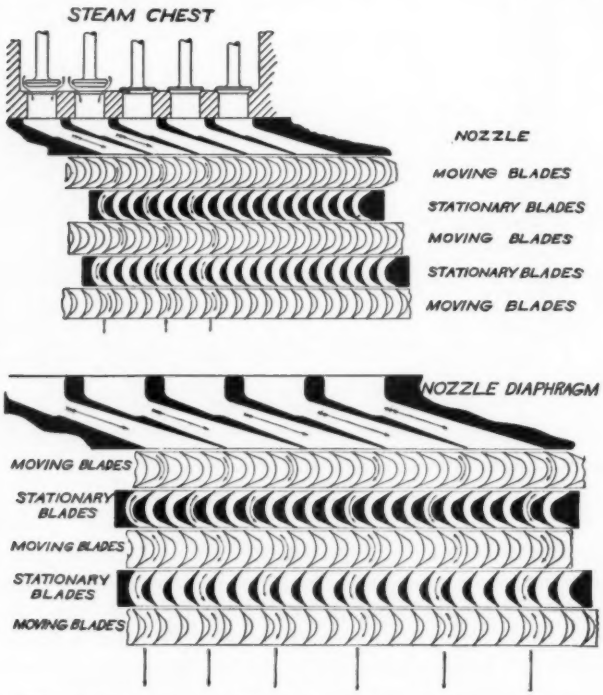
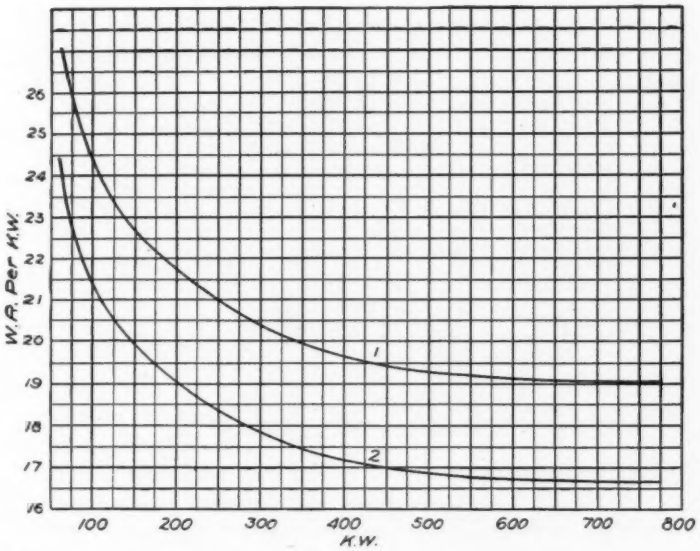


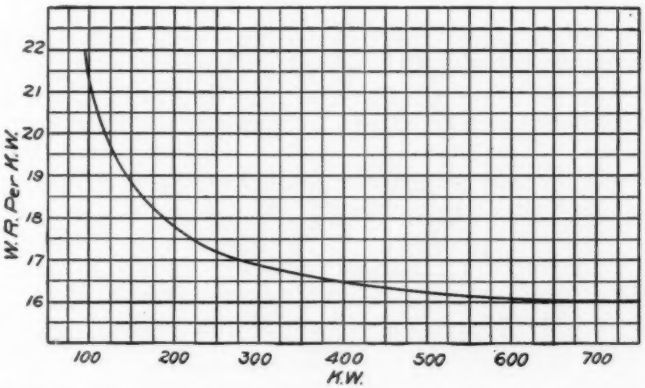
Fig. 1.—Diagram of Steam Nozzles and Vanes, Curtis Steam Turbine.

velocity as a compromise of shaft speed allowed. If very low velocities are sought, then more stages are necessary, and its resemblance to the Parsons turbine in that particular respect will appear. Economy results are shown in the curves herewith illustrated.

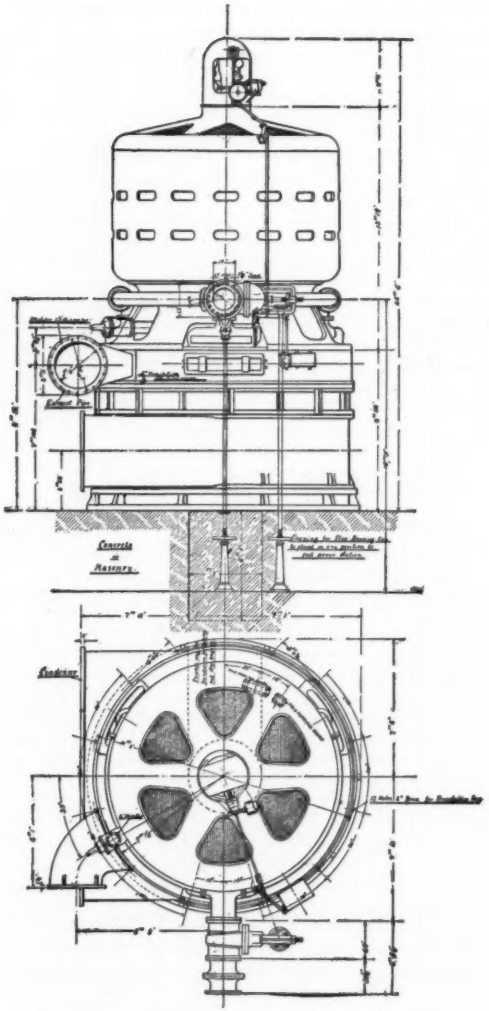
Upper curve, without superheat; lower, with 150 degrees superheat (Curve I.)



Curve I.—Curve of Water Consumption, Curtis Steam Turbine. 140 Pounds Initial Pressure.

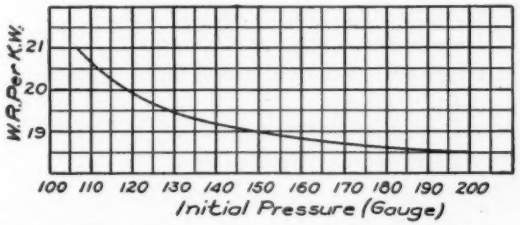


Curve II.—Curve of Water Consumption, Curtis Steam Turbine. 200 Pounds Initial Pressure.



5,000 K.W., CURTIS LAND STEAM TURBINE, 500 R.P.M., MOUNTED WITH GENERATOR.

Same conditions with 150 degrees superheat, and 200 pounds steam pressure (Curve II).



Curve III.—Curve of Water Consumption, Curtis Steam Turbine. Varying Initial Pressures.

This curve shows steam consumption at different initial pressures (Curves III).

The turbine illustrated in the cut on opposite page is one of the large power units used for stationary work.

The Curtis marine turbine is, in general principles, similar to the turbine used for stationary purposes, but differs from it by an additional arrangement of reversing vanes being provided on the outer rim of the ahead-going discs of the low-pressure stage.

This type of turbine seems admirably suited for marine purposes, both on account of its smaller space when placed in comparison with the piston engine and its less weight and greater simplicity of mechanism. A turbine of this description is installed in the yacht *Revolution*, of which previous mention has been made in this paper.

The following is the most recent available data for a detailed comparison of space and weight required by Curtis marine turbines and reciprocating engines of 8,000 horsepower each.

Volumetric:

Small turbine (500 R.P.M.), .11 cubic foot per I.H.P.

Large turbine (350 R.P.M.), .2 cubic foot per I.H.P.

Reciprocating engine (220 R.P.M.), .45 cubic foot per I.H.P.

Linear, with reference to length only:

Small turbine (15 feet 3 inches to center of bearings), .5 length of engine.

Large turbine (18 feet 3 inches to center of bearings), .65 length of engine.

Weights:

Motors, small turbine (500 R.P.M.), 53 tons.
large turbine (350 R.P.M.), 81 tons.
reciprocating engine (220 R.P.M.), 94 tons.

Propellers and shafting:

Small turbine (500 R.P.M.), 22.5 tons.
Large turbine (350 R.P.M.), 30 tons.
Reciprocating engine (220 R.P.M.), 41 tons.

Other Types.

Besides the steam turbines here described, there are in existence a number of others, some of which have acquired a very high degree of excellence in the fields for which they are specially adapted. Among them should be mentioned the Dow compressed-air turbine, which is used for operating certain mechanisms of torpedoes with most excellent results. The Seger double wheel parallel-flow turbine and the Schultz compound multiple-expansion turbine are two of the more recently developed machines, the former being of the DeLaval type, the latter of the Parsons.

In conclusion I wish to state that this article is by no means written with a view to filling an existing need in turbine literature, but rather to meet the wish of the Secretary of the American Society of Naval Engineers in his aim to present the discussion in a general way. Though it be perhaps quite incomplete, it may afford an opportunity to those who, by special adaptation, both as designers and manufacturers, are competent and willing to follow up the subject in more specific articles in the Journal. At the same time, I also beg to express gratitude to Mr. A. M. Mattice, Chief Engineer of the Westinghouse Machine Co., for the use of several charts, tables and illustrations; to Mr. T. W. Kellogg, of the General Electric Company, for cuts of the Curtis turbine; to Mr. E. S. Lea, of the DeLaval Steam Turbine Company, for cuts of the DeLaval steam turbine, and to the "Street Railway Journal" for cuts of the Rateau turbine.

U. S. S. *DES MOINES.*

GENERAL DESCRIPTION—OFFICIAL TRIAL.

By Lieutenant Walter Ball, U. S. N., Member.

The U. S. S. *Des Moines* is a sheathed protected cruiser of the *Denver* class, contracted for by the Fore River Engine Company of Weymouth, Mass. (now the Fore River Ship and Engine Company of Quincy, Mass.) from Government plans and specifications, the contract price being $1,065,000, and the time for completion thirty months, computed from December 14, 1899. The keel was laid August 28, 1900, and the vessel was launched September 20, 1902.

The contract required a speed of 16½ knots for four consecutive hours, with not more than one inch air pressure in the ash pits and upon a trial displacement of 3,200 tons.

For failure to attain the required speed $25,000 was to be deducted for each quarter knot between 16½ and 16 knots, and $50,000 for each quarter knot between 16 and 15½ knots. If the vessel failed to reach a speed of 15½ knots the Secretary of the Navy could reject her, or accept her at a reduced price. The total weight of machinery was limited to 427 tons. This penalty weight includes main engines and boilers, all auxiliaries and fixtures in engine rooms and fire rooms, heating system, water in boilers, condensers, pipes, pumps and stern tubes, all as in steaming condition, but does not include capstan, windlass, steering gear or reserve feed water. The penalty for overweight was fixed at $500 a ton.

HULL.

The hull is constructed of mild steel of domestic manufacture, on frames spaced 36 inches apart, with outer plating of 15-pound plates throughout (except strake connected with third longitu-

dinal, 17½ pounds), and sheathed with 4-inch Georgia pine and 26, 28 and 30-ounce sheathing copper. The planking is secured to the plating by ¾-inch brass screw bolts, each bolt having a brass nut on its point inside for additional security. The Bureau of Construction and Repair has approved fitting light manganese-bronze plating in the wake of the chafe of anchors and anchor gear.

HULL DATA.*

Length between perpendiculars, feet and inches	292- 1½
on L.W.L., feet and inches	292- 1½
over all, feet and inches	309-10
Beam, feet and inches	44- 0
Ratio of length to beam	6.64
Depth (midship section), top of main deck beam to bottom of frame, feet and inches	30- 4
Draught forward, sea-going trim, normal, feet and inches	15- 3½
aft, sea-going trim, normal, feet and inches	16- 2½
mean, sea-going trim, normal, feet and inches	15- 9
Displacement for above draft, tons	3,200
per inch immersion at L.W.L., tons	22.3
Area of immersed midship section, square feet	602
Center of gravity of water line aft of midship section, feet and inches	3-10
buoyancy above bottom of keel, feet and inches	9- 3½
aft of midship section, ship on even keel, feet	0.63
Transverse metacenter above center of buoyancy	10- 1
Center of gravity above bottom of keel, feet	16
Coefficient of fineness in extreme dimension, per cent	52
of midship section, per cent	87
L.W.L., per cent	73
Cylindrical coefficient of fineness, per cent	60
Number of frames, spaced 3 feet	100
W.T. compartments, including 26 cofferdam compartments	161

MAIN ENGINES.

There are two triple-expansion, four-cylinder engines of the vertical, inverted type, placed abreast of each other in separate watertight compartments, each engine supported by twelve steel columns. The crosshead guides are outboard, and the cranks

* A complete list of details of construction will be found on pages 1,111 to 1,116 in No. 4, Vol. XV of JOURNAL, under the description of the *Cleveland*.

turn inboard in the ahead motion. The cylinders are arranged as follows from forward: L.P., H.P., I.P. and L.P. The H.P. has one piston valve, the I.P. two and the L.P.'s have one double-ported slide valve each.

The link motion is the double-bar Stephenson type, with one crosshead for the I.P. valves.

The bedplates are in three pieces, of cast-steel, ∩ section, bolted together; the forward section is cast with a bed for the main air pump.

In the starboard engine room, on the upper platform, is a 12-H.P. electric motor which is arranged to turn either engine. There is also a ratchet arrangement for turning by hand.

DATA OF MAIN ENGINES.

Cylinders, number for each engine	4
H.P., diameter, inches	18
I.P., diameter, inches	29
F.L.P., diameter, inches	35
A.L.P., diameter, inches	35
Valves, H.P. (one), diameter, inches	11
I.P. (two), diameter, inches	11
L.P. (two), slide, inches, length, 25½; width, 39½; port, length	37
Valve stems, H.P. (one), diameter, lower ends, inches	2
through valve, inches	1⅝
at balance piston, inches	1 3/32
L.P. (two), diameter, lower ends, inches	2
through valves, inches	1⅝
at balance piston, inches	1 3/32
L.P. (two), diameter, lower ends, inches	2½
through valves, inches	1¾
at balance piston, inches	1 7/16
Piston rods, diameter, inches	4½
length from piston to center crosshead pin, inches	53½
axial hole, inches	2
Connecting rods, center to center, inches	67
diameter, upper ends, inches	4½
lower ends, diameter, inches	4½
axial hole, inches	2
Main steam pipe (steel), diameter, inches	6
exhaust pipes (two), to condensers (copper), diameter, inches.	12½
Crosshead pins, diameter, inches	5½

Crosshead pins, length in bearing, inches	10
Crank shaft, diameter, inches	9½
axial hole, diameter, inches	5
coupling discs, diameter, inches	17
thickness, inches	2½
bolts (six), taper, mean diameter, inches	2
journals, diameter, inches	9½
length, inches	11
axial hole, diameter, inches	5
Crank webs, width, inches	10½
thickness, inches	5½
Thrust shaft, diameter, inches	9½
axial hole, inches	5⅜
length, feet and inches	7– 4
coupling discs, diameter, inches	17
thickness, inches	2½
collars, number, each shaft	11
diameter, inches	14
distance between collars, inches	3
thickness of collars, inches	1⅝
surface, total, both engines, square inches	1,020.8
Line shaft, diameter, inches	9
axial hole, diameter, inches	5⅜
length feet	25
Stern-tube shaft, diameter, inches	9
axial hole, diameter, inches	2 to 5⅜
length, feet and inches	38– 5
Propeller shaft, diameter, inches	9
axial hole, diameter, inches	2 to 5⅜
length, feet and inches	20– 3
Total length of shafting from forward end of thrust shaft to after end of propeller shaft, feet and inches	99–10½
Main condenser (¼ boiler steel), diameter, inside, feet and inches	4– 4½
between tube sheets, feet and inches	9– 2
tubes, number	2,004
outside diameter, inch	⅝
thickness	No. 18 B.W.G.
cooling surface, square feet	3,004

The propellers are three-bladed, of manganese-bronze, designed by the contractors; the driving surfaces of the blades are true screws with adjustable pitch from 12 feet to 11 feet 6 inches. The blades are bent back through an angle of 8 degrees 15 minutes.

VALVE READINGS OF THE MAIN ENGINES TAKEN FROM WORK.

Connecting rods, between centers, inches.....67.
Eccentricity of all valves, inches..... 2.

Steam valves.....	H.P. *Port.*		I.P. *Port.*		F.L.P. *Port.*		A L.P. *Port.*		H.P. *Starboard.*		I.P. *Starboard.*		F.L.P. *Starboard.*		A L.P. *Starboard.*	
Valve travel, inches.....	$3\frac{29}{64}$		4		$4\frac{1}{16}$		$4\frac{1}{16}$		$4\frac{13}{16}$		$4\frac{25}{64}$		$4\frac{5}{32}$		$4\frac{25}{64}$	
Number and kind of valve.....	One piston.		Two piston.		Double-ported slide.				One piston.		Two piston.		Double-ported slide.			
Diameter and dimensions, inches....	11		11		.....		.....		11		11		.....		.....	
	Top.	Bot.	Top.	Bot.	Top.	Bot.	Top.	Bot.	Top.	Bot.	Top.	Bot.	Top.	Bot.	Top.	Bot.
Steam lap, inch.....	$\frac{13}{32}$	$\frac{13}{64}$	$\frac{13}{64}$	$\frac{13}{64}$	$\frac{13}{16}$	$\frac{13}{64}$	$\frac{1}{2}$	$\frac{27}{64}$	$\frac{13}{32}$	$\frac{13}{32}$	$\frac{13}{64}$	$\frac{13}{16}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{13}{64}$
Exhaust lap, inch.....	$-\frac{5}{32}$	$-\frac{1}{16}$	$-\frac{21}{64}$	$-\frac{1}{64}$	$\frac{7}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{1}{4}$	$-\frac{1}{16}$	$-\frac{5}{32}$	$-\frac{3}{8}$	0	0	$\frac{1}{4}$	0	$\frac{13}{64}$
Angular advance, degrees.....	$36\frac{1}{2}$	$36\frac{1}{2}$	$34\frac{1}{2}$	$34\frac{1}{2}$	40	40	40	40	37	37	35	35	39	39	38	38
Steam lead, angle, degrees.....	$9\frac{1}{2}$	11	9	11	12	$13\frac{1}{2}$	15	15	$8\frac{1}{2}$	$12\frac{1}{2}$	$8\frac{1}{4}$	$11\frac{1}{2}$	$12\frac{1}{4}$	$15\frac{1}{2}$	$12\frac{1}{2}$	$15\frac{1}{2}$
lead, inch.....	$\frac{5}{32}$	$\frac{1}{16}$	$\frac{17}{64}$	$\frac{1}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{17}{64}$	$\frac{23}{64}$	$\frac{1}{4}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{23}{64}$	$\frac{13}{32}$
Cut-off, inches.....	$23\frac{1}{2}$	$20\frac{7}{16}$	24	$21\frac{3}{4}$	$22\frac{13}{32}$	$22\frac{17}{32}$	$20\frac{5}{32}$	$19\frac{1}{2}$	$23\frac{1}{16}$	$21\frac{13}{32}$	$23\frac{7}{16}$	$21\frac{23}{32}$	$22\frac{13}{16}$	$20\frac{11}{32}$	$23\frac{1}{2}$	$20\frac{13}{16}$
decimal.....	.770	.681	.800	.717	.730	.670	.751	.662	.768	.715	.781	.730	.760	.699	.775	.697
Exhaust release, inches.....	$3\frac{11}{32}$	$4\frac{3}{32}$	$2\frac{13}{16}$	$3\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{13}{32}$	$3\frac{3}{8}$	$3\frac{7}{32}$	$3\frac{11}{32}$	$3\frac{5}{16}$	$3\frac{5}{16}$	$3\frac{3}{8}$	$2\frac{5}{16}$	$2\frac{1}{16}$	$2\frac{11}{32}$	$2\frac{23}{32}$
decimal.....	.122	.134	.093	.114	.087	.086	.120	.114	.117	.118	.118	.112	.077	.089	.077	.09
Compression, inches.....	$2\frac{5}{32}$	$2\frac{1}{16}$	$1\frac{53}{64}$	$1\frac{41}{64}$	$5\frac{5}{64}$	$4\frac{53}{64}$	$3\frac{13}{32}$	$3\frac{5}{16}$	$1\frac{13}{16}$	$1\frac{11}{16}$	$1\frac{53}{64}$	$1\frac{53}{64}$	$4\frac{5}{16}$	$3\frac{5}{16}$	$4\frac{5}{32}$	$3\frac{5}{16}$
decimal.....	.070	.068	.057	.055	.170	.164	.113	.118	.06	.056	.055	.065	.143	.118	.134	.119
Steam opening, inches.....	$1\frac{3}{32}$	$1\frac{7}{64}$	$1\frac{5}{64}$	$1\frac{13}{64}$	$1\frac{1}{16}\times 2$	$1\frac{7}{64}\times 2$	$1\frac{1}{2}\times 2$	$1\frac{5}{32}\times 2$	$1\frac{3}{32}$	$1\frac{3}{32}$	$1\frac{5}{64}$	$1\frac{5}{16}$	$1\frac{5}{64}\times 2$	$1\frac{5}{16}\times 2$	$1\frac{1}{2}\times 2$	$1\frac{13}{64}\times 2$
Exhaust opening.....	Full port.		Full port.		Full port.		Full port.		Full port.		Full port.		Full port.		Full port.	

PROPELLER DATA.

Diameter, feet and inches	10- 6
Pitch at trial, feet and inches	11- 9
Developed area, each propeller, square feet	34
Projected area, each propeller, square feet	29
Disc area, each propeller, square feet	86.59
Greatest width of blade on circle, inches	41 1/8
Diameter ÷ pitch	.893
Distance of center of hub above lowest point of keel, feet and inches	5- 6
Tip of blade immersed at trial displacement, feet	5

The propellers used on the official trial are shown on the opposite page.

PUMPS.

All the pumps were designed and made by the Fore River Ship and Engine Company. In each fire room there is one main feed pump of the outside-packed single-plunger type, 12 inches by 12 inches by 7 inches. These pumps draw from the feed tanks and hotwells, and deliver only to the boilers.

On the forward bulkhead in each engine room is an auxiliary feed pump of the same size and type as the main pumps.

The auxiliary pumps draw from the sea, bilge, feed tanks and the main and secondary drains, and deliver to the sea, to the boilers, to the fire main or to the ash ejectors.

There is a fire and bilge pump in each fire room, and one in each engine room. These pumps are of the single, inside-packed, plunger type, 7 inches by 12 inches by 7 inches. There are also two water-service pumps of same size and type, one in each engine room.

There is a hotwell pump in each engine room, which may be used for drawing water from hotwells, air-pump suctions, reserve feed tanks, and from the side of the ship above the water line, for taking on board fresh water. They discharge only to the feed tanks. These pumps are the same size and design as the fire and bilge pumps.

BOILERS.

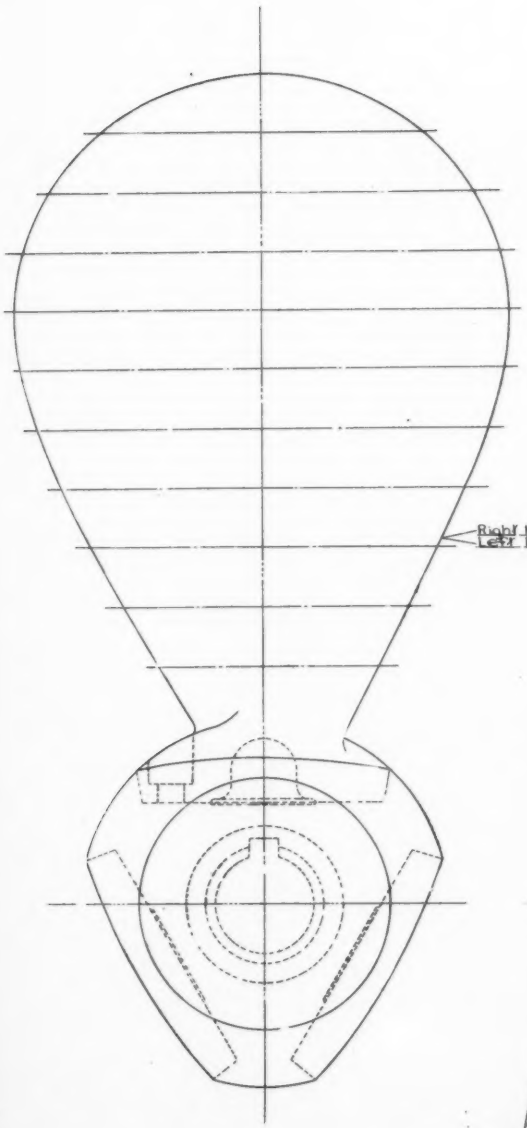
There are six B. & W. boilers, placed four in a forward watertight compartment and two in an after watertight compartment.

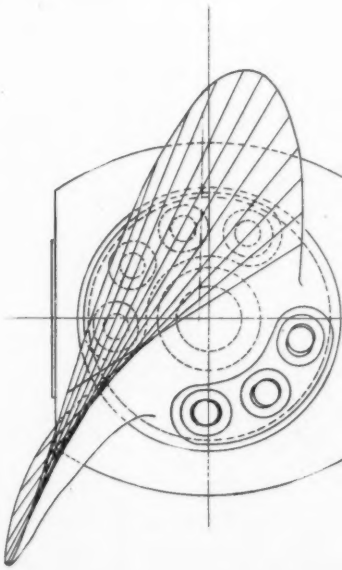
For a detailed description and illustration see page 1122, Vol. XV, No. 4, of this JOURNAL, under the description of the *Cleveland*.

U. S. S. Des Moine

Propeller used on Official Tr
Scale 3" = 1ft.

Designed H.P.	2250
Designed Revolutions	172
Both wheels turn Inboard.	
Diameter	10ft. 6".
Pitch	11ft. 9.
Projected Area	29 sq. ft. ea
Developed Area	34 sq. ft. ea
Disc Area	86.59 sq. ft.
Pitch ratio (P/D)	1.12.





Des Moines

on Official Trial.

e: 3"-1ft.

.P. 2250.

evolutions 172.

Turn Inboard.

ft. 6.

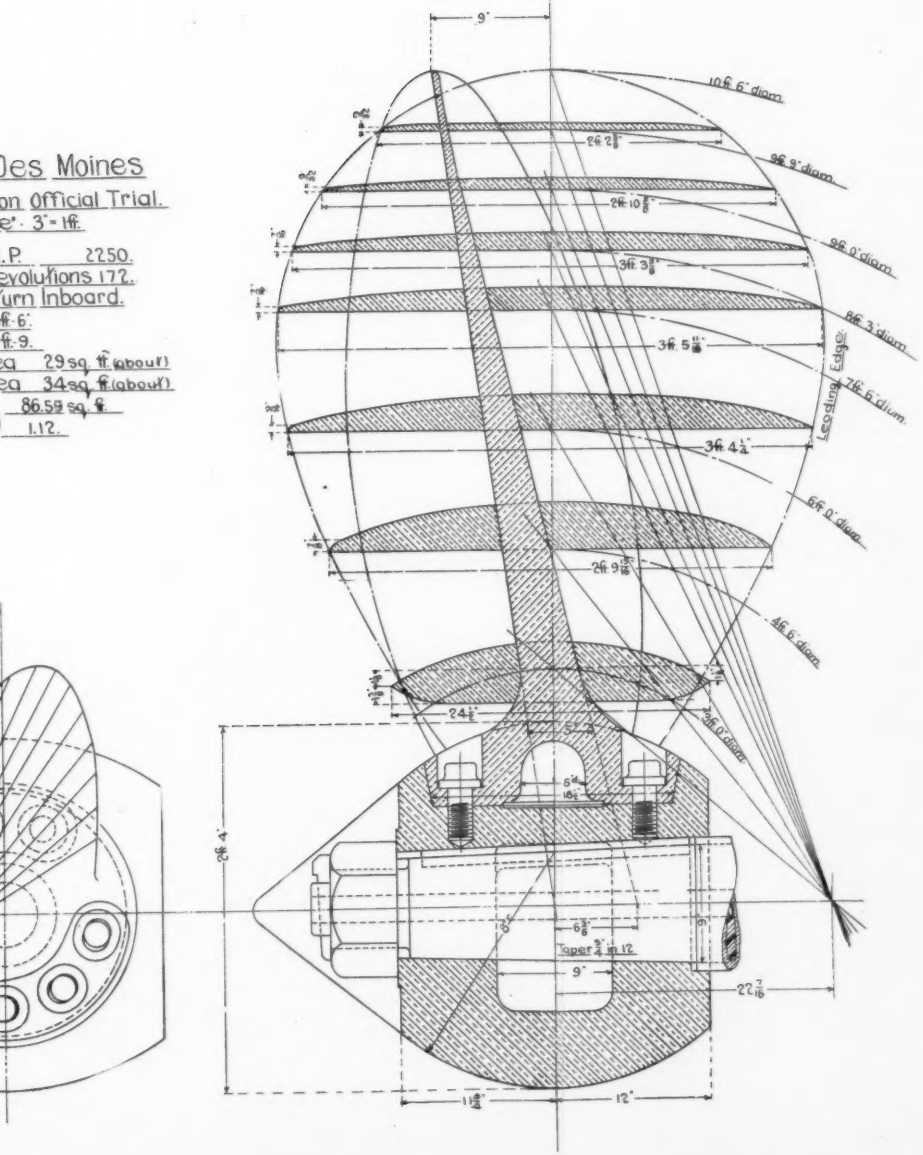
ft. 9.

ea 29 sq. ft. (about)

ea 34 sq. ft. (about)

86.59 sq. ft.

1.12.



COAL SUPPLY.

Below the protective deck are thirteen watertight bunker compartments, including two between engine and boiler rooms and one large bunker just forward of the boilers. Above the protective deck are eight watertight bunker compartments. The capacity of these bunkers is 280.8 tons for the upper bunkers and 696.5 tons for the lower bunkers.

There are chutes from the upper bunkers leading directly to doors in the fire rooms. This allows coal to be taken from above without disturbing that in the lower bunkers, an arrangement which undoubtedly has its advantages, though it has been obtained on this ship at the expense of valuable bulkhead space in the fire rooms.

OFFICIAL TRIAL.

The official trial took place on the Cape Ann course on December 5, 1903.

The exact weight of machinery, including water in boilers, condensers, etc., in accordance with the contract requirements, is given in the following table:

	Pounds.	Tons of 2,240 pounds.
Engines (including propellers)	223,390.15	99.727
Boilers and appurtenances	251,102	112.099
Fixtures in engine and fire rooms	252,249	112.611
Smoke pipes	71,349	31.852
Distilling apparatus	162,93.25	7.273
Stores and spare parts (not completed)	24,677	11.01
Heating apparatus (not completed)	15,920.5	7.107
Tools in workshop	18,923	8.457
Refrigerating plant	9,809.5	4.424
Water in boilers at 410 degrees	46,398	20.713
condensers at 60 degrees	6,718	3.334
pumps at 150 degrees	2,824	1.261
pipes at 60 degrees, 102 degrees, 150 degrees.	9,816	4.379
stern tubes at 60 degrees	1,270	.567
main feed tanks at 150 degrees, ⅞ full	5,677	2.365
hotwell filter tanks at 150 degrees	10,527	4.699
evaporators at 212 degrees	4,808	2.146
distillers at 60 degrees	127	.056
fresh-water tanks at 70 degrees, ⅞ full	1,500	.669
feed heaters at 150 degrees	513	.229
	973,891.4	434.978

OFFICIAL TRIAL,

Time.	Number of counter.	Revolutions per minute.	Steam pressures. In boilers, above the atmosphere.	Steam pressures. At engines, above the atmosphere.	Steam pressures. In receiver, above a perfect vacuum.		Steam cut-off in decimals of the stroke, from the beginning. H.P. cyl.	Steam cut-off in decimals of the stroke, from the beginning. I.P. cyl.	Steam cut-off in decimals of the stroke, from the beginning. L.P. cyls.	Opening of throttle valve in tenths.	Vacuum in condenser, in ins. of mercury.
h. m. s.					*1st.*	*2d.*					**PORT**
9·55·38½	397,827	...	276	249	95	30				10	28.5
10·10·38½	400,558	182.1	277	250	95	30	Top..... .770	Top..... .800	Top, for'd..... .730; aft..... .751	10	28.5
10·25·38½	403,398	189.3	...	245	90	27	Bottom..... .681	Bottom..... .717	Bottom, for'd..... .670; aft..... .662	10	28.5
10·40·38½	406,251	190.2	265	250	94	29				10	28.4
10·55·38½	409,105	189.6	...	235	89	27				10	28.5
11·10·38½	411,977	191.5	273	245	93	29				10	28.4
11·25·38½	414,824	189.8	...	230	89	27				10	28.5
11·40·38½	417,667	189.5	283	250	97	31				10	28.3
11·55·41½	420,433	...	...	225	87	28				10	28.3
12·03·18½	421,895	...	...	250	98	31				10	28.2
12·18·18½	424,696	186.7	285	237	90	29				10	28.4
12·33·18½	427,504	187.2	...	224	87	28				10	28.5
12·48·18½	430,294	186	267	244	93	29				10	28.2
1·03·18½	433,114	188	...	222	84	26				10	28.3
1·18·18½	435,904	186	275	247	95	29				10	28
1·33·18½	438,740	189.1	...	248	95	29				10	27.5
1·48·18½	441,596	190.4	284	240	93	27				10	27.7
2·01·19	444,127	...	...	245	91	28				10	28
Average	...	188.34	276	241	92	28.5				...	28.25
											STARBOARD
9·55·38½	397,827	...	276	240	90	29.5				10	27.5
10·10·38½	400,530	180.20	277	245	94	29.5				10	27.5
10·25·38½	403,360	188.66	...	245	95	30				10	27.5
10·40·38½	406,201	189.40	265	250	95	30				10	27.5
10·55·38½	409,020	187.93	...	250	95	30				10	27.5
11·10·38½	411,870	190	273	250	95	30				10	27.5
11·25·38½	414,700	188.66	...	245	95	30				10	27.5
11·40·38½	417,530	188.66	283	250	95	30				10	27.5
11·55·41½	420,380	190	...	240	93	29.5				10	27.5
12·03·18½	421,895	...	...	245	94	30				10	27.5
12·18·18½	424,685	186	285	250	95	30				10	27.5
12·33·18½	427,490	187	...	235	91	29				10	27.5
12·48·18½	430,270	185.33	267	245	95	30				10	27.5
1·03·18½	433,100	188.66	...	245	95	30				10	27.5
1·18·18½	435,900	188.66	275	245	95	30				10	27.5
1·33·18½	438,740	189.33	...	250	95	30				10	27.5
1·48·18½	441,600	190.66	284	250	95	30				10	27.5
2·01·19	444,132	194.76	...	245	95	30				10	27.5
Average	...	188.25	276	245.8	94.3	29.86				...	27.5

Top..... .768
Bottom..... .715

Top..... .781
Bottom..... .730

Top, for'd..... .760; aft..... .775
Bottom, for'd..... .699; aft..... .697

ENGINE ROOM.

Double strokes, feed pump.	Double strokes, water service pump.	Double strokes, bilge pump.	Double strokes, hotwell pump.	Temperatures.					Revolutions or double strokes per minute.					Air pressure in ins. of water, ash pans.
				Engine room.	Fire Room.	Injection water.	Discharge water.	Feed water.	Air pump.	Circulating pump.	Blowers.			
											For st'b'd.	For port.	After.	
ENGINE														
...	...	...	...	91	...	...	...	125		...	...	...	...	...
32	50	55	30	91	85	46	72	120		240	...	...	...	...
33	52	53	35	91	...	46	72	115		195	...	...	...	...
34	56	52	40	91	85	46	72	110		186	...	...	...	...
35	54	100	36	92	...	47	72	105		186	...	...	...	...
36	50	120	30	92	85	47	72	100		186	...	...	...	...
37	52	122	34	92	...	48	73	92		186	...	...	...	...
38	50	126	40	92	85	48	73	85		186	...	...	...	...
...	...	...	...	92	...	48	73	84		...	...	...	...	...
...	...	...	...	95	...	...	...	82		188	...	...	...	...
36	48	124	40	95	85	48	72	82		186	...	...	...	...
38	46	120	38	95	...	48	72	81		188	...	...	...	...
44	46	122	42	95	85	48	72	80		186	...	...	...	...
46	44	120	44	96	...	47	72	80		162	...	...	...	...
48	36	110	40	96	85	47	72	98		160	...	...	...	...
38	38	110	40	96	...	46	70	110		160	...	...	...	...
35	32	120	42	96	85	46	70	92		160	...	...	...	...
...	...	...	...	96	...	46	70	110		...	...	...	...	...
38	46.7	103.9	38	...	...	47	71.8	97.3		183.7	...	...	...	...
ENGINE														
...		27	...	...	...	...	...	...		...	360	400	524	.5
...		27	105	...	...	46	87	124		150	400	370	490	.9
...		27	...	...	90	46	89	124		160	...	...	...	...
...		27	...	90	...	46	90	125		162	400	390	315	.9
...		27	64	...	...	47	87	150		165	...	...	...	...
...		27	...	...	88	47	88	150		165	410	410	290	1
...		27	...	...	...	48	92	148		162	...	...	...	...
...		27	53	92	...	48	90	148		162	390	405	370	1.1
...		27	...	...	...	48	90	150		162	...	...	...	...
...		27	...	...	...	...	...	...		...	...	...	...	...
...		27	...	94	...	48	90	132		153	390	390	380	1
...		27	44	...	...	48	90	122		153	...	...	...	...
...		27	...	...	88	48	92	132		159	400	410	400	1.1
...		27	...	...	...	47	94	122		155	...	...	...	...
...		27	42	...	...	47	92	145		162	400	420	380	1.1
...		27	...	92	...	46	94	160		158	...	...	...	...
...		27	...	...	86	46	92	138		162	370	405	390	1.1
...		27	40	...	...	46	90	138		155	...	...	...	...
...		...	...	...	...	47	90	138		159	...	..	...	.97

Running at intervals. Attached. Attached. Attached.

The reducing valves between the boilers and engines on main steam pipes were removed by the contractors with the permission of the Navy Department.

Unfortunately, the amount of coal sacked and weighed for the trial was insufficient, and no reliable data relative to the coal consumption was obtained.

The advantage of having the forced-draft blowers above the protective deck was shown by their efficient working and good results. The boilers performed satisfactorily, and there was not the slightest tendency to priming. The air pressure in the fire rooms during trial was at all times less than 1.1 inches.

The coal used was picked Pocahontas.

The engines ran with a very noticeable absence of vibration. There were no heated bearings or journals, with the exception of the starboard high-pressure crosshead pin. Water was used very freely on this journal, but the engines were not slowed down. The amount of oil used on all running parts was very excessive. The smooth running of the engines showed good workmanship and very excellent adjustment.

The auxiliary exhaust was used partly on feed-water heaters and partly in L. P. receivers.

COMMENTS ON THE DESIGN AND INSTALLATION OF MACHINERY.

In the starboard engine room, the electric motor for turning the engines is located on the upper gratings. This motor is of greater size than is necessary for the duty, and crowds the already inadequate space available for oiling and attendance on the upper grating. Because of the heat and moisture of this position, the durability of the motor is certain to be affected. These are sufficient reasons for the removal of this motor and for the installation in its stead of the usual design of steam turning engine.

The outside-packed plunger pumps have not proved their advantages over the inside-packed piston type. On the trial there was a great deal of leakage which was made the basis for a rumor that 50 tons of make-up feed water was used. Not only is it difficult to keep the plungers properly packed, but the in-

On page 185, for lines 11 and 12, read as follows:

in as high a ratio as the fifth power of the diameter and the third power of the revolutions of the parts revolving. The DeLaval

On page 196, for equation (1) read

$$V = \sqrt{2g \frac{n}{n-1} p_1 v_1 \times 144 \left\{ 1 - \frac{v_2}{v_1} \left(\frac{v_1}{v_2} \right)^n \right\}}, \quad . \quad (1)$$

For insertion in Vol. XVI, No. 1, page 236.

ADDITIONAL TRIAL DATA.

PERFORMANCE.

Steam pressure at boilers (per gauge), pounds	276
H. P. steam chest, S. engine (per gauge), pounds	245.8
P. engine (per gauge), pounds	241
1st receiver, S. engine, absolute, pounds	94.3
P. engine, absolute, pounds	92
2d receiver, S. engine, absolute, pounds	29.86
P. engine, absolute, pounds	28.5
Vacuum in condensers, in inches of mercury	S., 27.5; P., 28.25

MEAN EFFECTIVE PRESSURES IN CYLINDERS IN POUNDS PER SQUARE INCH.

Main engines, starboard, H.P.	120.40
I.P.	45.094
F. L.P.	13.49
A. L.P.	16.12
port, H.P.	120.15
I.P.	45.30
F. L.P.	15.156
A. L.P.	15.403
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	44.906
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, port	45.398

REVOLUTIONS PER MINUTE.

Main engines, starboard	188.145
port	188.34
Pumps, circulating, starboard	159
port	183.7
feed, double strokes per minute	38
auxiliary, water service	46.7
bilge	103.9
hotwell	38
Blower engines	392
Speed of ship, in knots per hour	16.6461
Slip of propeller in per cent. of its own speed, based on mean pitch,	S., 23.5; P., 23.59
Air pressure in ash pits, inch of water	0.97

INDICATED HORSEPOWER.

Main engines, starboard H.P.	846.1
I.P.	838.86
F. L.P.	377.5
A. L.P.	451.19
total	2,513.65
port H.P.	845.2
I.P.	843.6
F. L.P.	424.66
A. L.P.	431.56
total	2,545.02
Pumps, air, main, attached to main engine.	
Circulating pump, starboard engine (H.P., 65.87; L.P., 17.747)	83.617
port engine	83.617
Feed pumps, two main and two auxiliary	104.792
Bilge pumps, starboard engine	1.896
port engine	1.896
Water-service pumps, starboard engine	1.896
port engine	1.896
Hotwell pumps, starboard engine	1.896
port engine	1.896
Ventilating engines, for ship, electric; for engine rooms, electric.	
Blower engines, for forced draft in fire rooms	23.47
Dynamo engines	38.6
Collective of all main engines and air pumps	5,058.74
main engines, air, circulating and feed pumps	5,339.766
and auxiliary engines in operation during trial	5,399.613
all machinery during trial, per square foot of G.S.	17.9987
H.S.	0.41535
Main engines, air, circulating and feed pumps, per sq. ft. of G.S.	17.799
H.S.	0.41075

DRAFT AND DISPLACEMENT.

Draft, mean, for trial, forward, feet and inches	15–2 9/16
aft, feet and inches	16–2 9/16
average, feet and inches	15–8 9/16
Displacement at mean draft on trial, tons	3,190.86

creased friction of the packing lowers the efficiency of the pumps and makes it difficult to start them against a pressure.

The crowded condition of the engine rooms was commented upon very freely by the Inspection Board.

The removal of the evaporating plant to the spar deck or elsewhere, and the omission of one auxiliary condenser, would relieve the present crowding in the engine rooms. Removing the ash ejectors, which are not efficient, and dispensing with the unnecessary air lock between the fire rooms, will tend to improve the boiler-room installation.

Much of the oil and water-service piping around the engine frames could be dispensed with, thus improving the appearance of the engine room and producing less complication.

The cooling water from the main condensers is led aft a distance of 25 feet before it is discharged overboard, for which eccentricity of design no obvious reason appears.

The ventilation of the engine rooms would be much improved if the sides and top were removed from the tunnel through the engine-room hatch on the berth deck, railings and gratings being substituted; this arrangement would not impair to any great extent the present watertight subdivision of the ship.

The present installation of the evaporating plant and the crowded condition of the engine rooms will make any repairs, except those of a light nature, almost an impossibility in the tropics. With water-tube boilers fresh water is an absolute necessity. The evaporators can be scaled and repaired only with great discomfort and difficulty,—consequently their present location not only affects directly the durability of the motive power, but also the present cruising efficiency of the ship.

S. S. *MONGOLIA*—PACIFIC MAIL STEAMSHIP COMPANY.

BUILT BY THE NEW YORK SHIPBUILDING COMPANY.

By L. D. Lovekin, Esq.

The S. S. *Mongolia*, recently completed by the New York Shipbuilding Co., of Camden, N. J., for the Pacific Mail Steamship Company, made her trial trip successfully January 27, 1904. This ship is the largest yet completed in America.

The *Mongolia*, and her sister ship, the *Manchuria*, were originally contracted for by the Atlantic Transport Line, but were subsequently taken over by the Pacific Mail Company and modified slightly for their trade on the Pacific, between San Francisco and the ports of Japan and China. The *Mongolia* is of the intermediate type, similar in design and arrangement to the large vessels of this class built by Harland and Wolff, of Belfast, Ireland. The speed attained on trial was 16 knots. Provision is made for 350 first-class passengers. The crew will consist of about 200 people. Chinese steerage accommodations on the upper deck provide for 1,300; this space is available for cargo when not so occupied.

The over-all length is 615 feet 8 inches; between perpendiculars, 600 feet; beam, 65 feet; molded depth, 51 feet 3 inches. On a load draught of 33 feet 6 inches her displacement is 26,820 tons. There are seven decks: Orlop, lower, middle, upper, shelter, bridge and boat deck. She is rigged as a four-masted, fore-and-aft schooner, with straight stem and elliptical stern. The shelter deck extends clear fore-and-aft, with deck houses amidships for main saloon, pantry and gallery, with staterooms for saloon passengers and ship's officers. Away aft is a deck house for steam-steering gear and hospitals, with entrance to quarters below.

The main saloon is finished in quartered oak, with dull Flemish finish. The staircase leads to the social hall, and this opens to the music room and library above the saloon. A large light-well in the center provides extra light for the saloon, and is surrounded by a suitable railing and settees. Above this is a large skylight tastefully fitted with stained glass. This room is equipped with mahogany book cases, writing desks and piano. The smoking room is aft on the boat deck. This room is finished in dark quartered oak. It has a skylight of stained glass, and the portholes all have rectangular sliding windows of stained glass with appropriate designs.

Every provision is made for the comfort and convenience of passengers on the long trip across the Pacific. The great size and steadiness of the ships of this type will probably make them as great favorites on the Pacific as they are on the Atlantic.

DATA.—GENERAL DIMENSIONS.

Length over all, feet and inches	615– 8
between perpendiculars, feet	600
Breadth, feet	65
Depth, feet and inches	51– 3
Load draught, feet and inches	33– 6
displacement, tons	26,820
Dead weight capacity, tons	14,461
Block coefficient	.717
Cargo capacity, cubic feet	934,080
Tank capacity, salt water, tons	3,640
fresh water, tons	1,042
Bunker capacity, tons	1,938
Engines:	
Number	2
Type	Four-cylinder, quadruple.
Cylinders, diameters, inches	30, 43, 63, 89
stroke, inches	60
I.H.P. at sea	10,000
Revolutions at sea	80
Steam pressure, pounds	215
Shafting:	
Crank, diameter, inches (4-inch hole)	18
Line, diameter, inches (6-inch hole)	17⅛
Thrust, diameter, inches (6-inch hole)	28¼ and 17¾
Propeller (mean), diameter, inches (6-inch hole)	18¼

Condenser, cooling surface, each, engine, square feet	7,500
Air pump, direct connected, diameter, inches	30½
Propellers, three blades each :	
Number	2
Diameter, feet and inches	18- 6
Pitch, feet and inches	23- 6
Helicoidal area, each propeller, square feet	86.6
Boilers :	
Scotch	4 single end, 4 double end.
Working pressure, pounds per square inch	215
Diameter, feet and inches	14- 6
Length, single end, feet and inches	10–10½
double end, feet and inches	19- 4½
Tubes, diameter, inches	2½
number, single end, each boiler	410
double end, each boiler	820
length over all, single end, feet and inches	7- 6½
double end, feet and inches	7–10½
Thickness of stay tubes, inch	½
plain tubes	No. 8 B.W.G.
Furnaces :	
Inside diameter, inches	40½
Number each, single end, each boiler	3
double end, each boiler	6
Lengths of grates, feet and inches	5- 3
Heated forced draft.	
H.S. each, single end, square feet	2,367
double end, square feet	4,702
Total, square feet	28,276
G.S. each, single end, square feet	53
double end, square feet	106
Total, square feet	636
H.S. ÷ G.S.	44.5
I.H.P. ÷ G.S.	15.75
H.S. ÷ I.H.P.	2.8

MAIN ENGINES.

Arrangement of Main Engines.—The vessel is fitted with twin screws and with engines of 10,000 I.H.P. The engine room is very spacious, extending the entire width of the ship, and 45 feet 6 inches fore-and-aft. All this area is available with the exception of the small corner spaces occupied by the engine-room wing bunkers. The absence of a midship bulkhead between the engines still further adds to the appearance and spaciousness of

the engine room. The height from the engine-room floor plates to the skylights is 70 feet. A view from the upper gratings, there being five stages altogether, gives one an impression of great depth.

Engines and Cylinders.—The engines are four-cylinder, quadruple-expansion, of the usual marine type, with Stephenson link-valve motion, arranged for propellers turning outboard. The sizes of cylinders are: H.P., 30 inches; 1st I.P., 43 inches; 2d I.P., 63 inches; L.P., 89 inches, with a common stroke of 5 feet. The designed pressure at the engines is 200 pounds. The cylinders are arranged from forward aft, as follows: High pressure, 2d intermediate, low and 1st intermediate. The distance between centers is 8 feet 5 inches, 14 feet 3 inches, and 8 feet 5 inches, respectively.

The sequence of cranks is H.P., L.P., 2d I.P. and 1st I.P., when the engines are in ahead motion—the respective crank angles being 96 degrees, 106 degrees, 96 degrees and 62 degrees.

Framing.—The cylinders are supported on eight cast-iron housings of box section. The two forward back housings run clear from the cylinder feet to bed plate; the two after back housings run to the top of condenser, which extends only half the length of engines from the after end. The cylinders are free to expand independently of each other, each one being bolted only to its own housings. The housings are joined at their upper ends by horizontal cast-iron girders of box section. This construction is characteristic of the New York Shipbuilding Company's engines, and gives a very secure connection, while at the same time it allows independent expansion of the cylinders. The overhang of the L.P. valve chest is carried on shoes which are free to move on the horizontal girders.

Bed Plate.—The bed plate is of cast iron, in four parts, of box section throughout, with lightening holes reinforced. The columns are fitted with hand-hole plates and utilized as oil tanks.

Valves.—The main valves are of the piston type, with the exception of the L.P., which is double ported slide. One piston valve, each of 16⅜ inches and 22 inches diameter, respectively,

supply the H.P. and 1st I.P. cylinder, while the 2d I.P. has two of 21 inches diameter, driven from a cast-steel crosshead.

Assistant Cylinders.—The L.P. and 2d I.P. valve gears are balanced with the Lovekin-Thom Assistant Cylinder. These cylinders are located over the valve stems, which have extensions for pistons as in an ordinary balance cylinder. The 2d I.P. assistant cylinders take their steam from the L.P. receiver through a sleeve on the stem. The L.P. assistant cylinder takes its steam from the 1st I.P. receiver reduced to 85 pounds. This allows a small assistant cylinder to be used for the heavy gear. The smooth working of these heavy valve gears under normal conditions shows them to be relieved of all strains due to inertia and gravity. By throttling down the supply to the L.P. assistant cylinder it was observed that the consumption of steam was practically nothing. This accords with the theory of their design, there being no exhaust, as the desired balance is obtained simply by alternate compression and expansion arranged to suit the forces expected. The only consumption of steam possible is that due to losses by radiation and leakage.

Pistons.—The main pistons are conical. Those of the H.P., 1st I.P. and L.P. are of cast steel, and of the 2d I.P. of cast iron. Lockwood & Carlisle packing rings are used in the L.P. piston, the others having three spring rings of the usual type. The follower bolts screw into composition plugs in the piston bodies. Metallic packing is used on the H.P. and 1st I.P. rods and valve stems, fibrous packing being used for all others.

Piston Rods, Connecting Rods and Crossheads.—The piston rods are of mild open-hearth forged steel, 9 inches diameter. The 2d I.P. and L.P. rods carry extension tail rods of 6¾ inches diameter. The crossheads are of the same material as piston rods and secured by tapered fit. The crosshead shoes are cast iron, adjustable, lined with white metal. The connecting rods are also of mild steel, 11 feet 3 inches between centers, with fork-end tops provided with phosphor-bronze boxes.

Shafting.—The crank shafts are of the built-up type, mild steel, 18 inches diameter, with a 4-inch axial hole. The thrust, line and tail shafts are of the same material, 17¾ inches, 17⅛ inches and 18¼

inches diameter, respectively, with 6-inch axial hole. The thrust shaft has eight collars, 28¼ inches diameter, running between adjustable horseshoe bearings of the usual type.

Around the flange on the forward end of tail shaft a cast-iron ring is fitted, and just aft of this, but clear of it, is a stop secured to the framing of the shaft boss. The purpose of this gear is to prevent the tail shaft working aft should breakage occur in the line shaft. Efficient trolley gears provide a means for quickly withdrawing the tail shafts for examination, etc. The stern tubes are of cast iron in two sections. The nuts on the stern gland are worked by rack gearing from a worm wheel and pinion.

Propellers.—The propellers are three bladed, built up, with manganese-bronze blades and cast-iron hubs, arranged to allow adjustment of pitch from 21 feet 8 inches to 25 feet 4 inches. The diameter of tips of blades is 18 feet 6 inches.

Condensers.—The condensers are of cast iron, built in abreast of the two after cylinders. The tube-cooling surface of each is 7,500 square feet. The circulating water enters at the top and leaves at the bottom, passing through twice the length of tubes. The tubes are ¾-inch outside diameter, of No. 18 B.W.G. brass, tinned inside and out. The tube sheets are of Muntz metal.

Direct-Connected Pumps.—The direct-connected pumps on each engine are attached to the condenser and operated by links from the 1st I.P. crosshead. The main air pump is 30½ inches diameter and 30 inches stroke. The other direct-connected pumps are: One 6-inch feed pump, one 6-inch bilge pump and one 5-inch fire and sanitary pump. There is also a 4½-inch diameter, 15-inch stroke, hot salt-water pump on port engine only. Aspinwall inertia governors are fitted on the pump levers and connected to the butterfly valves.

Reversing Gear.—The reversing gear is of the "all-round" type, double, 7½-inch by 7½-inch engines, secured to the inboard 2d I.P. housing. They are connected by worm gearing to the reverse shaft just above. The reversing engines are quickly and easily started and stopped by the change valve between steam and exhaust lines. The reverse arms are fitted with slots to allow independent "linking up" of all engines.

Turning Engines.—The turning-gear engines are duplicates of the reversing engines and secured to the inboard side of each condenser. They connect by double worm gearing to a cast-steel gear on the main shaft.

Feed Pumps, Feed Heaters and Grease Extractors.—There are four main feed pumps of the vertical, simplex, double-acting piston type, 11 inches by 8 inches by 26-inch stroke, built by Dean Bros. These are similar in style to the well-known Weir pumps. Steam to these pumps is regulated by an automatic float in the suction chambers. The two auxiliary feed pumps are vertical, duplex, 12 inches by 7 inches by 12 inches, and 9 inches by 6 inches by 10 inches, also built by Dean Bros. The feed water, after leaving the main feed pumps, passes through a Quiggins feed heater of the vertical cylindrical type. Steam to the coils of the feed heater is taken from the high-pressure exhaust or from the main feed-pump exhaust as desired. From the feed heater the feed passes through a Railton & Campbell grease extractor of the cartridge type, thence to the main boilers, through main or auxiliary lines. Ample connections allow the feed water to be handled in almost any way desirable or necessary, cutting out heater and filter, one or both, using the main or the auxiliary feed pumps or the direct-connected pumps.

Circulating Pumps.—The main circulating pumps are centrifugal, with connections 16 inches diameter, driven by independent 10-inch by 10-inch vertical engines of the New York Shipbuilding Company's design.

Service Pumps.—The ballast pump is vertical duplex, 12 inches by 14 inches by 12 inches. Two other vertical duplex pumps, 6 inches by 6 inches by 6 inches and 5¼ inches by 4 inches by 5 inches, are for pumping fresh water for the various uses required. The independent water-service and sanitary pump is also vertical duplex, 7 inches by 8 inches by 8 inches.

Auxiliary Condenser.—A Wheeler auxiliary condenser of 1,050 square feet cooling surface is located on the port side middle platform with its own air and circulating pumps attached, size 10 inches by 12 inches by 12 inches by 12 inches.

Evaporating Plant.—A Reilly evaporator is located below in the forward end of the port engine room with a capacity of 50 tons of fresh boiler feed per 24 hours. In connection with this are the evaporator feed pump and two vertical cylindrical distillers of capacity of 5,000 gallons each per 24 hours. They are supplied with circulating water from the auxiliary duplex feed pumps or the ballast pump.

Electric Plant.—The electric-lighting plant is located on a level with the middle platform in a recess aft of the main engine room. It consists of three General Electric Company direct-connected generators of 25 K.W. capacity each. The engines are compound, 6½ inches and 10½ inches by 7 inches stroke, run at 400 revolutions. The generators are direct-connected, compound-wound for pressure of 110 volts. The switch board has the usual complete equipment of voltmeter, ammeters, ground detectors, circuit breakers, etc. The lighting installation consists of over 900 lamps of 16 candlepower each.

Refrigerating Plant.—The refrigerating plant is located below, aft of the main engine room in the space between the main shafts. The machine is built by the J. & E. Hall Company of England, and uses carbonic anhydride gas. The engine is cross compound, cylinders 11 inches and 22 inches by 15-inches stroke. The compression cylinders are of wrought steel, arranged in tandem with the steam cylinders. The bed plate of the machine is made large, to incorporate the necessary auxiliaries. It contains the condenser for its own engine, also two condensers for the CO_2. The attached pumps consist of air pump for the engine condenser, feed pump to deliver discharge of same to feed tank, and circulating pump to supply cooling water for the condensers. An independent duplex pump, 4¾ inches by 6½ inches by 6 inches, is also fitted for circulating water to the condensers when required.

The two evaporators for the refrigerating gas are located aft of the machine. The cold brine from these is circulated through the chambers by two vertical, duplex 4¾ inch by 6½ inch by 6-inch pumps. A complete distributing system of manifolds, with thermometers, allows the operation of the cold-storage plant in any way desirable. The total refrigerated space is about 9,000

cubic feet. There is also an ice-making plant arranged for twenty cans of about 28 pounds each.

Machine Shop.—A very completely equipped machine shop is located on the upper deck abreast of the engine room on the port side. The machinery equipment consists of the following tools arranged to be driven by a vertical 6½-inch by 7-inch New York Safety Power Company engine:

One Kelly 16-inch shaping machine.

One Barnes 25-inch drill press.

One Slater sensitive drill.

One double-heavy emery wheel grinder.

One 16-inch back-geared screw-cutting lathe, 14 feet between centers.

One Forbes adjustable pipe-threading machine.

One 24-inch grindstone.

The tool rooms are located on the middle deck abreast of the engine room, from which they are entered from the upper grating.

MAIN BOILERS.

Arrangement.—There are eight main boilers, Scotch, return-tubular type, four double-ended and four single-ended. The double-ended boilers are located abreast of each other, just forward of the cross bunker that extends between engine and boiler rooms. The single-enders are similarly arranged forward of these, facing them, so the same fire room serves for the forward end of double-enders and for the single-enders. Chutes run from upper side bunkers to each side of the double fire room. Another cross bunker extends across the ship forward of the boiler compartment, and a trolley service transports the coal from both the cross bunkers to fire rooms.

Heated Forced Draft.—The main boilers are fitted with the New York Shipbuilding Company's heated forced draft. The results of the trial show this system to be very efficient and satisfactory. At no time was there any trouble in maintaining full boiler pressure for the maximum steam demand made by the engines. This was done with an air pressure of 1 inch in the ash pits. There are three Sturtevant blowers, 96 inches in diameter, driven

by double engines, 8¼ inches by 5½ inches stroke. One is located over each fire-room hatch on the grating below the shelter deck. Air is drawn from over the boilers and heated in the usual tube heaters in the uptakes before being admitted to the furnaces.

Uptakes and Smokepipes.—The uptakes all unite in a common smokepipe of elliptical section, 10 feet 9 inches wide and fourteen feet 3 inches fore-and-aft.

Fire-room Ventilation.—There is an 84-inch Sturtevant fan with 6-inch by 5-inch double engines provided for ventilating the fire rooms.

Ash Hoists.—The ash hoists are steam, of the direct-lifting type, designed by the New York Shipbuilding Company. Large ash chutes are conveniently located inboard, with continuous-flushing arrangement.

Auxiliary Boiler.—A small auxiliary boiler is located on the middle deck aft of the after fire-room hatch. It is single-ended, return-tubular, of the dry-back type, 5 feet 6 inches diameter, 7 feet 4 inches between heads. The pressure is 215 pounds.

Steam Piping.—The steam piping systems are carefully arranged and very complete, provision being made for overhauling without shutting down necessary auxiliaries, such as dynamos. All the distributing systems can be operated from the manifolds in the engine room at the forward bulkhead. Reduced pressure of 100 pounds is used for all auxiliaries except main feed pumps.

DECK MACHINERY.

There are nineteen winches of the horizontal double-engine type, built by the Hyde Windlass Company. Two each, with engines 8 inches by 14 inches, are located at all hatches up to No. 9, while No. 10 has one with engines 10 inches by 16 inches. All these are fitted with gypsy heads, drums and change gearing, as required for the service intended.

The anchor windlass engines are located on the upper deck. They are vertical, 18 inches by 14 inches, also built by the Hyde Windlass Co. The windlass is located on the shelter deck and receives its motion from the engines through bevel and worm gearing. It is extremely massive and strong to suit the requirements of so large a ship.

The steering engines are located aft in the deck house provided for same. They are built by the Williamson Bros. from the type used by Harland & Wolff. There are two complete double vertical engines mounted on sliding beds, so arranged that either may be brought into or thrown out of gear as desired. This is accomplished by means of adjusting screws which move the whole engine bed, the steam pipes being run in circular loops to admit the necessary movement. Each engine is double, 13 inches by 14 inches, with piston valves, and the usual arrangement of floating change valve to control movement. The engines are connected to the rudder quadrant by means of bevel gears between the horizontal and vertical auxiliary shafts for each engine. The gearing and all other parts are of ample weight and strength. The quadrant connects to the tiller proper through heavy coil springs which take up jar. The reversing valve of the steering engines is controlled from the bridge through shafting and bevel gearing. They can also be controlled from the after bridge or engines direct. No hand steering gear is provided, but a spare tiller is fitted and arranged for tackle connection with the after winch.

Ample provision is made everywhere for sanitation and ventilation. There is a Clayton fire-extinguishing and fumigating apparatus on the upper deck aft of the engine room. It consists of a gas generator and direct-connected blower and engine with the necessary pipe connection to various holds and compartments. This can be used to send gas for either purpose anywhere throughout the ship.

NOTES.

The following notes of trial results were made by Commander A. B. Canaga, U. S. Navy, who witnessed the trial of the *Mongolia*, as a guest of the New York Shipbuilding Company, and made a report concerning it to the Chief of Bureau of Steam Engineering:

TRIAL RESULTS.

The trial consisted of a four-hour run at sea. The speed was not accurately ascertained, and was estimated 16 knots. The revolutions varied from 82 to 88 per minute, with a mean of 85.

Steam in boiler, pounds	205
at throttle, pounds	200
Vacuum, inches	26
I.H.P., both engines	10,400
Injection, degrees F	40
Discharge, degrees F	118
Hotwell, degrees F	125
Feed water, degrees F	141
Revolutions of forced-draft blowers	230
Air pressure at blowers, inches water	1.6
front connections, inches	1.3
in ash pits, inches	.8
Temperature of air entering heater, degrees F	48
ash pits, degrees F	230
hot gases in front connection, degrees F	650
at base of smoke pipe, degrees F	450
fire rooms (single), degrees F	50
(double), degrees F	80

NOTES.

BRITISH WARSHIP BUILDING IN 1903.

The year has been one of considerable activity in naval affairs, and there is matter for congratulation almost in every direction of Admiralty procedure. The change in the attitude of the Lords Commissioners of the Admiralty in regard to the status and rank of engineers was the first cause for satisfaction during the year, and closer examination into Lord Selborne's scheme, and the preliminary arrangements already made for carrying it out, have tended to increase the commendation first expressed. Following this have come several other reforms for improving the efficiency of the Service, not the least important being the change in the age of retirement of superior officers, while indication has also been afforded of the Admiralty's earnestness in the matter of accuracy of gun fire and efficiency in engineering generally. There has been a continuation of the enlightened policy in regard to dockyard administration and equipment, and this year especially many new machine tools have been installed, while much progress has been made in the comprehensive scheme which, in the next three years, will result in the whole of the mechanism in the dockyards being run by electric power. These establishments have not launched the same amount of new work as in previous years. This is largely owing to the fact that two years ago the volume of work was so great, and the condition of the yards so congested, that it was deemed prudent to reduce the number of new ships ordered. But this year more work has been given out, and at the present time the Royal establishments have on the stocks, or in preparation for laying down, four battleships and four armored cruisers, the total tonnage being considerably in excess of that at the end of several preceding calendar years. There has, however, been a very large addition made to naval ships floated from the private works of the kingdom.

TABLE I.—FIGHTING VESSELS LAUNCHED.

		No.	Tons.	Indicated horse-power.	Value of ships completed.
					£
In 1903.	Dockyards	4	28,290	42,800	2,384,000
	Private yards (H.M.S.)	31	120,456	277,300	9,848,000
	(foreign)	7	4,237	17,190	368,000
	Total in 1903	42	152,983	337,290	12,600,000
In 1902.	Dockyards	5	51,560	77,000	3,723,000
	Private yards (H.M.S.)	10	40,494	108,000	3,208,000
	(foreign)	7	990	8,550	145,000
	Total in 1902	22	93,044	193,550	7,076,000
In 1901.	Dockyards	8	64,910	114,300	4,901,200
	Private yards (H.M.S.)	24	144,190	275,000	11,002,600
	(foreign)	7	2,442	47,500	340,000
	Total in 1901	39	211,542	436,700	16,243,800
In 1900.	Dockyards	4	5,230	11,200	394,600
	Private yards (H.M.S.)	17	30,374	125,800	2,531,600
	(foreign)	8	25,827	42,750	1,925,000
	Total in 1900	29	61,431	179,750	4,851,200
In 1899.	Dockyards	6	66,900	78,000	4,901,100
	Private yards (H.M.S.)	12	53,222	111,000	3,791,000
	(foreign)	16	47,170	124,000	3,767,000
	Total in 1899	34	167,292	313,000	12,459,100
In 1898.	Dockyards	8	70,955	84,800	4,441,000
	Private yards (H.M.S.)	22	70,033	168,800	4,242,000
	(foreign)	18	52,365	144,250	3,480,000
	Total in 1898	48	193,353	397,850	12,163,000

The dockyards have greatly reduced their output, as shown in Table II, but it must be remembered that these establishments are largely—although by no means entirely—for the overhauling of our warships—*i. e.*, for the maintenance of the fleet in a satisfactory degree of efficiency; the contention being that new work is undertaken principally in order to keep the *personnel* educated in modern practice. This year, for instance, seventeen ships have undergone a very extensive refit in the dockyards, apart altogether from the very considerable amount of small work involved in connection with re-commissioning. It is true

that the practice has been developed this year of having extensive overhauls done by contractors, payment being according to a schedule of rates agreed upon, and during the past year thirteen vessels have been so dealt with by various firms on the Admiralty list; but the great increase in the fleet and the limitation of space in the dockyards, which has necessitated this distribution of repair work, has resulted in our dockyards being kept as busy as heretofore. It may also be said in this connection that very satisfactory results have accrued from the introduction of the system this year of having the contract ships completed for commission at the works of the builders, instead of sending them to the dockyards to have the finishing operations done there.

TABLE II.—FOURTEEN YEARS' PRODUCTION OF BRITISH NAVY SHIPS.

Year.	Dockyard.		Private Yard.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.
1890	8	22,520	13	42,475	21	64,995
1891	8	68,100	10	39,150	18	107,250
1892	9	50,450	13	90,750	22	141,200
1893	9	32,400	5	1,919	14	34,319
1894	8	26,700	19	4,825	27	31,525
1895	8	70,350	28	66,412	36	136,762
1896	9	70,970	26	36,515	35	107,485
1897	4	31,885	22	34,111	26	65,996
1898	8	70,955	22	70,033	30	140,988
1899	6	66,900	12	53,222	18	120,122
1900	4	5,230	17	30,374	21	35,604
1901	8	64,910	24	44,190	32	209,100
1902	5	51,560	10	40,494	15	92,054
1903	4	28,290	31	120,456	35	148,746
Totals	98	661,220	252	774,926	350	1,436,146

Operations have steadily progressed on several ships launched in 1902, and to be finished in 1904. The battleship *New Zealand* (18 Niclausse Boilers.—*Ed.*) will be launched at Portsmouth in February, and a new battleship of the same, the *King Edward VII* class, put down in its place. The *Devonshire* will be launched in the early spring from the Chatham establishment, where also a new battleship of the same type will be laid down. Pembroke

has made good progress with the *Duke of Edinburgh*, and has laid down the *Warrior*,* and Davenport will shortly lay down another battleship.

A result of the large number of launches in 1903 is that there are comparatively few naval ships now on the stocks in private works. There are two armored cruisers practically ready for launching, and three, ordered two or three months ago, in the initial stage. The remainder of the vessels are all small craft, so that it is to be hoped that the naval programme for 1904–5 will not be delayed to the same extent as has been the case in some past years. There is a prospect of the new ships to be laid down being hurried forward, so that their keels may be laid in the early summer; and from every point of view we trust that this idea will be carried out.

TABLE III.—THE PRODUCTION FROM EACH NAVAL YARD.

Yard.	1903.		1902.		Total for 14 years.	Average for 14 years.
	No.	Tons.	No.	Tons.	Tons.	Tons.
Portsmouth.....	1	9,800	...	...	173,431	12,388
Chatham	...	...	2	20,880	180,362	12,883
Devonport.....	1	16,350	2	20,880	148,768	10,626
Pembroke.....	...	...	1	9,800	127,920	9,137
Sheerness.....	2	2,140	...	...	31,299	2,236
	4	28,290	5	51,560	661,780	47,270

It is unnecessary to write of the vessels launched during the year at any great length, as they have already been fully described in "Engineering." Four of the vessels floated are battleships of the *King Edward VII* class, the prototype having been launched at Devonport; the *Dominion*, at Vickers' yard at Barrow-in-Furness; the *Commonwealth*, from the Fairfield Works, and the *Hindustan*, from Messrs. Brown's works, at Clydebank, on Saturday last. These vessels represent Sir William White's latest battleship design at the Admiralty, being vessels of 16,350

* The four ships of this class are to carry oil fuel, and, therefore, special arrangements are made to stow oil fuel in the double bottom.—*Editor*.

tons displacement, and they are the largest yet ordered for the British Navy, and represent each a capital of over £1,300,000 ($6,318,000). Ten years ago the largest sum devoted to one ship was about £900,000 ($4,374,000), and here we have an indication of the great cost involved in the effort to attain the highest degree of defensive and offensive qualities, with good speed, on comparatively limited displacement. Although 16,350 tons is large for a battleship, it is only about half the displacement of the largest merchant ships now launched. In addition to the four vessels of the *King Edward VII* class, there fall to be included the two battleships which are to be taken over from the Chilian naval authorities. The *Libertad*, built by the Vickers Company, is to take the historical name of *Triumph*, while the *Constitution*, constructed at Elswick, will revive the renowned name of *Swiftsure*. These vessels represent a very satisfactory compromise of all the elements of design, and have a power and speed which, for their size, is far in excess of that obtained by our ships. It is a satisfaction to know that the Admiralty propose to take them over without making any alterations, and we hope that an opportunity may arise in early maneuvers for thoroughly testing their fighting qualities in comparison with those of our ships. We have thus launched six battleships this year, which must be regarded as a satisfactory addition to our fleet for twelve months.

In addition, three armored cruisers have been floated—the *Hampshire*, from the Elswick Works of Sir W. G. Armstrong, Whitworth and Co.; the *Antrim*, from the Clydebank Works of Messrs. John Brown & Co., Limited; and the *Carnarvon*, from the Govan Works of Messrs. William Beardmore & Co. These vessels, with three others, almost ready for launching—the *Devonshire*, at Chatham; the *Roxburgh*, at the London and Glasgow Works; and the *Argyll*, at the Greenock Works of Messrs. Scott & Co.—belong to the improved County Class. The chief improvement introduced is in the increased thickness of armor, and the substitution of one 7.5-inch gun for two 6-inch guns in the forward and aft gun house. The new vessels have a displacement of 10,700 tons, and their engines are designed to de-

velop 21,000 indicated horsepower. The later County boats have been excelling in speed on their full-power trials, giving from 23½ to 24 knots, so that those later ships, with their improved fighting qualities and this high speed, will certainly be very satisfactory cruisers. The cruisers since ordered, however, still further excel them, though naturally their displacement and their cost have been further increased. Six of these later ships of the *Duke of Edinburgh* Class, of 13,550 tons displacement, have been ordered. There has since been introduced the practice of making the engines of all these vessels uniform, so that as far as possible spare parts may be utilized in any of the ships. This practice was formerly aimed at where one firm built more than one ship; but this is the first occasion where a similar design has been adopted for a class, the units of which have had their machinery from different works.

Two third-class cruisers are in this year's list of launches—the *Amethyst*, which was launched from the Elswick Works, and the *Topaze*, from Laird's Works, at Birkenhead. These vessels are of 3,000 tons displacement, but the interesting point in connection with them is that the first mentioned is being fitted with Parsons steam turbines, while the second will have ordinary reciprocating engines. Both hulls are alike, and there will thus be available for Admiralty comparative tests in the summer of next year vessels differing only in their propelling machinery. We understand that the opportunity will be embraced of having very exhaustive trials as to the relative efficiency of the systems. Such a test has not yet been made by the British Admiralty. The *Velox*, a torpedo-boat destroyer, is shortly to undergo a series of trials; in her case, however, a comparison cannot be made between turbines and triple-expansion engines driving ships of exactly the same submerged form. The committee appointed by the Cunard Commission have recently had comparative trials of the two latest vessels for the Brighton Company's service between Newhaven and Dieppe, the *Brighton* being fitted with turbine machinery and the *Arundel* with reciprocating machinery. Here, again, the under-water forms are different, the two vessels being of slightly different dimensions; but the comparative data,

when collated, will certainly assist the Commission in answering the very important question addressed to them as to whether turbine machinery should be adopted in the new high-speed Atlantic liners.

The year has been one of considerable activity as regards the launching of destroyers, fifteen having been floated—five from the works of Palmers, who have been particularly successful with this type of craft; four by Laird, of Birkenhead; three by Hawthorn, Leslie & Co., two by Yarrow, and one by Thornycroft. These vessels are of the improved type. Their maximum speed is 25½ knots, but as they are of heavier scantlings, with a high forecastle and a greater coal-carrying capacity, they are likely to be much more efficient. A higher speed will be possible in a seaway than with the original small 30-knot craft. Fifteen more of these vessels have been ordered during the past year from the five firms named. The submarine boats launched from Messrs. Vickers' Works at Barrow-in-Furness, where ten larger vessels of the type are now under construction, make up a very good year's contribution to the Navy, embracing nearly every type.—"Engineering," Dec. 25, 1903.

WARSHIP STEAM TRIALS IN 1903.

During the year which has just closed twenty-nine new ships for the Navy passed through their steam trials. The number includes four battleships, eight armored cruisers, one protected cruiser, and a sloop; while three gun boats, which had been re-engined, have also been tried. In addition, there were ten torpedo-boat destroyers and five first-class torpedo boats. This number of vessels exceeds the average, and, in view of the high designed speed, the results are of special interest. In the previous year, there were sixteen ships, with two torpedo-boat destroyers; in 1901, fourteen large ships and eighteen torpedo craft; and in 1900, ten new ships and fifteen torpedo craft. The results of the trials of the larger ships are set out in Table I, and of the torpedo craft in Table II.

One feature of the results tabulated is due to the inclusion of

a larger variety of types of water-tube boilers. For instance, we have two battleships, one with Babcock & Wilcox boilers, and the other with Belleville boilers. These are the *Queen* and *Prince of Wales*. In both cases the machinery is alike, and the hull has, in each instance, been made from the same drawings; a comparison between the performance of these two ships may thus be justifiable. It is notable, in the first place, that in the Babcock & Wilcox boiler a larger allowance of heating surface is made for the same power, the ratio in the one case being 2.56 square feet of heating surface per unit of power, while in the case of the Belleville-boiler ship the proportion is 2.47 square feet per unit. At the same time the grate area is larger in the case of the Belleville boiler, there being 1 square foot of grate to 31.37 square feet of heating surface, as compared with 1 square foot to 33.5 square feet in the case of the Babcock & Wilcox steam generator. The coal-consumption results are distinctly in favor of the Babcock & Wilcox boilers, so far as these two ships are concerned, the apparent difference being about 20 per cent.; it would, however, be a mistake to dogmatize on these two isolated instances.

A more comprehensive trial, under exactly corresponding circumstances—and possibly, also, for a longer period under Service conditions—could alone yield results on which to base anything like a conclusive opinion. Moreover, the personal equation, as we have aforetime pointed out, must always be an important factor in the case. Of course, we do not presume to state that experience will not bear out the difference recorded above; the facts given will incline many to look forward, with very considerable interest, to the subsequent comparative trials of these and of other ships similarly conditioned.

The other two battleships in the list—the *Cornwallis* and the *Albemarle*—differ from those to which we have just referred in respect that they were designed to attain a speed of 19 knots, and for this reason greater weight was afforded to machinery and less to armor protection. The broadside belt was, therefore, reduced in the case of the 19-knot ships to 7 inches, as compared with 9 inches, in the *Queen* and *Prince of Wales;* this

Table I.—Results of Official Steam Trials of Warships Made During 1903.

Name of vessel.	Type of ship.	Builders of ship.	Makers of machinery.	Length in feet.	Displacement.	Type of boilers.	Heating surface.	Grate area.	First 30 hours' coal consumption.			Second 30 hours' coal consumption.			Full power.		
									Indicated horse-power.	Speed.	Coal per I.H.P. per hour.	Indicated horse-power.	Speed.	Coal per I.H.P. per hour.	Indicated horse-power.	Speed.	Coal per I.H.P. per hour.
					tons.		*sq. ft.*	*sq. ft.*		*knots.*	*lbs.*		*knots*	*lbs.*		*knots.*	*lbs.*
Cornwallis	Battleship	Thames Company	Thames Company	405	14,000	Belleville	43,310	1380	3724	10·9 log.	1.96	13,687	17.94 M.	2.09	18,201	18.984 M.	1.89
Albemarle	Ditto	Chatham Dockyard	Ditto	405	14,000	Do.	43,310	1380	3606	12.05 "	2.26	13,576	17·75 "	2.12	18,301	18 63 "	1.96
***Queen*	Ditto	Devonport Dock-yard	Harland & Wolff	400	15,000	Babcock and Wilcox	38,400	1146	3058	11.6 "	1.84	11,670	16.97 "	1.61	15,556	18.039 "	1.76
***Prince of Wales*	Ditto	Chatham Dockyard	Greenock Foundry	400	15,000	Belleville	37,018	1180	3128	10.45 "	2.21	11,669	17.043 "	2.08	15,364	†	2.02
Monmouth	First-class cruiser	London & Glasgow	London & Glasgow	440	9,800	Do.	50,316	1610	4711	15.676 "	1.83	16,326	20.49 log.	1.45	22,189	22.38 log.	1.97
Essex	Ditto	Pembroke Dock-yard	J. Brown & Co., Clydebank	440	9,800	Do.	50,306	1618	4642	14.043 "	2.03	16,138	19.97 M.	2.17	22,219	22.79 M.	2.22
Berwick	Ditto	W. Beardmore & Co.	Humphrys, Tennant & Co.	440	9,800	Niclausse	52,340	1656	4671	14.59 "	1.75	16,622	21.644 "	1.78	22,681	23.613 "	1.91
Donegal	Ditto	Fairfield Company	Fairfield Company	440	9,800	Belleville	50,330	1610	4678	14.75 "	2.07	16,350	22.356 "	2 07	22,173	23.568 "	2.16
Lancaster	Ditto	Armstrong Company	Hawthorn, Leslie, & Co.	440	9,800	Do.	50,388	1610	4643	13.43 "	2.1	16,044	22.03 "	2.16	22,881	24.01 "	1.94
Cumberland	Ditto	London & Glasgow	London & Glasgow	440	9,800	Do.	50,326	1615	4930	15.4 "	2.09	16,472	22.138 "	1.98	22,784	23.68 "	2.01
Suffolk	Ditto	Portsmouth Dock-yard	Humphrys, Tennant & Co.	440	9,800	Niclausse	52,340	1656	4954	14 4 "	1.89	16,350	21.2 log.	1.89	22,645	†	2.2
Eurydalus	Ditto	Vickers Company	Vickers Company	440	12,000	Belleville	51,585	1645.2	4780	14.457 "	1.99	16,510	20.45 M.	2.22	21,302	21.635 "	1.98
Challenger	Second-class cruiser	Chatham Dock-yard	Wallsend Company	355	5,880	Babcock and Wilcox	30,755	828	2636	13.5 M.	1 745	8,972	19.24 "	1 74	12,781	21.09 "	1.78
***Clio*	Sloop	Sheerness Dock-yard	Humphrys, Tennant & Co.	185	1,070	Niclausse	4,000	135	311	8.7 log.	2.32	1,041	13 0 log.	1.94	1,435	13.33 "	2.03
**Leda*	Torpedo gunboat	...	Fairfield Company	...	2,850	Thornycroft	12,800	265 2	1225	14.0 "	1.8	...	...	...	5,827	21.843 "	...
**Jason*	Ditto	...	Ditto	...	2,850	Do.	12,800	265.2	1203	15.0 M.	1.74	...	...	...	5,863	21.931 "	...
**Circe*	Ditto	...	Ditto	...	2,850	Do.	12,800	266.6	1211	14.318 "	1.76	...	...	...	5,821	21.624 "	...

** Mentioned elsewhere.—Ed. * Re-engined. M. = Measured mile. † Speed not taken on measured mile. Elsewhere stated as 18.+ and 25 knots respectively.

TABLE II.—RESULTS OF OFFICIAL STEAM TRIALS OF TORPEDO-BOAT DESTROYERS AND TORPEDO BOATS MADE DURING 1908.

Name of vessel.	Makers of hull and engines.	Length.	Displacement.	Type of boiler.	Heating surface.	Grate area.	Four hours' speed trials.		Four hours' coal consumption.		
							Indicated horse-power.	Speed.	Indicated horse-power.	Speed.	Coal per I.H.P. per hour.
		feet	*tons*		*sq. ft.*	*sq. ft.*		*knots*		*knots*	*lbs.*
**Erne*	Palmers Comp'y	225	540	Reed	15,514	319	6,957	25.606	7,108	25.395	2.25
Usk	Yarrow & Co.	225	550	Yarrow	16,000	270	7,633	25.873	7,739	25.372	1.79
Teviot	Ditto	225	550	Ditto	16,000	270	7,827	25.468	7,833	25.405	1.99
Itchen	Laird Brothers	220	549	Laird	14,880	233	6,967	25.642	6,842	25.25	2.46
**Ettrick*	Palmers Comp'y	225	540	Reed	15,514	319	7,119	25.568	7,067	25.313	2.33
**Exe*	Ditto	225	540	Ditto	15,514	319	7,114	25.64	6,856	25.292	2.11
Arun	Laird Brothers	220	549	Laird	14,880	233	7,028	25.722	6,885	25.39	2.68
Blackwater	Ditto	220	549	Ditto	14,880	233	6,939	25.656	7,237	25.414	2.62
**Foyle*	Ditto	220	549	Ditto	14,880	233	7,126	25.65	6,956	25.459	2.79
Velox	Armstrong (hull) Parsons Comp'y (engines)	210	440	Yarrow	13,200	252	Turbines	27.077	Turbines	27.124	...
†*No. 109*	Thornycroft	165	200	Thornycroft	6,200	105	2,871	25.296	2,778	25.213	2.809
†*No. 110*	Ditto	165	200	Ditto	6,200	105	3,030	25.333	2,885	25.12	2.68
†*No. 111*	Ditto	165	200	Ditto	6,200	105	2,926	25.436	3,001	25.321	2.73
†*No. 112*	Ditto	165	200	Ditto	6,200	105	3,030	25.311	2,991	25.28	2.49
†*No. 113*	Ditto	165	200	Ditto	6,200	105	2,934	25.122	2,830	24.753	2.80

* Mentioned elsewhere.—[Ed.]

† First class torpedo boats.

enabled the weight of machinery to be 1,580 tons, as compared with 1,530 tons in the *Queen* and 1,430 tons in the *Prince of Wales*. At the same time it was required that in the *Cornwallis* and the other five vessels of the class, 11.4 indicated horsepower should be realized per ton of machinery, whereas in the *Prince of Wales* the power to be attained is at the rate of 10.49 indicated horsepower, and in the *Queen* 9.80 indicated horsepower per unit of power. All the six vessels of the 19-knot class have now been tried, and have given very good results. The class includes the *Duncan*, *Russell*, *Montagu*, *Exmouth*, *Cornwallis* and *Albemarle*. The noticeable feature in connection with their machinery is the fact that it conforms fairly closely to the design adopted in the case of cruisers, there being four cylinders working on the triple-compound system. The high-pressure cylinder is 33½ inches; the intermediate, 54½ inches; and the two low-pressure cylinders, 63 inches in diameter, the stroke being 48 inches. The full power was to be realized with a piston speed of 960 feet, which is considerably higher than in preceding battleships, where 918 feet was the designed speed. But in our later battleships 960 feet has been adopted as the standard. It may not be without interest to note the results of the trials of all these ships, especially as we have already made important reservations in connection with comparisons:

TABLE III.—STEAM TRIALS OF SIX VESSELS OF THE "DUNCAN" CLASS.

Name.	30 hours' trial at one-fifth power.		30 hours' trial at 70 p. c. power.		8 hours' trial at full power.	
	I.H.P.	Coal consumption.	I.H.P.	Coal consumption.	I.H.P.	Coal consumption.
		lbs.		*lbs.*		*lbs.*
Duncan	3,755	2.05	13,717	1.90	18,222	1.95
Russell	3,767	2.4	13,685	2.14	18,199	2.10
Montagu	3,676	2.21	13,652	1.78	18,113	2.22
Exmouth	3,667	2.18	13,774	1.95	18,285	2.117
Cornwallis	3,724	1.96	13,687	2.09	18,201	1.89
Albemarle	3,606	2.26	13,576	2.11	18,301	1.96

The speed of the ships varied considerably, but there can be no question about their being able to steam 19 knots. The *Exmouth*,

on the measured mile, made 19.015 knots; and although the speed of the two ships tried on the measured mile during the past year fell slightly short of the 19 knots, there is no reason to question their ability to attain this speed under normal conditions.

But, as regards speed, the most interesting results are unquestionably those associated with the seven cruisers of the *County* class, included in Table I. These vessels, of which a large number have been ordered for the Navy (two having passed through their trials in 1902), have been the subject of much comment, alike as regards their gun power, their armor protection, their lines forward and their speed. It is not proposed here to enter into the question of the gun power, excepting to note that the later vessels of the class have had modifications to increase their ordnance and also the thickness of their side armor. As regards hollow lines, these have been continued, not only in the *Devonshire* class, but also in the *Duke of Edinburgh*, although in the latter the hull more closely approximates to a straight line; aft there is a slight hollow at the water line, which may assist the wake. But, after all, we are concerned here more with those machinery elements which make for speed, and reference may be made to the very interesting trials conducted with different forms of propellers. In the earlier of the *County* class the propellers were 16 feet in mean diameter, of 19 feet 6 inches mean pitch, and had an exposed area of 54 square feet. These vessels, however, did not quite come up to their full speed, even when the designed power was indicated. Thus, the speed of the *Bedford* was 22.7 knots; the *Kent*, 21.7 knots; the *Monmouth*, 22.38 knots, and the *Essex*, 22.79 knots. As the result of experiments, it was decided to adopt propellers of increased surface, and the later ships have been fitted with screws, still with four blades, but having a diameter of 15 feet 9 inches, a pitch of 20 feet, with a surface increased to 80 square feet. The result has been most marked.

The five ships which have since been tried have ranged in their speed from 23.568 knots to over 24 knots, so that the addition to the surface of the propeller has, for practically the same power, yielded an extra mile per hour to the speed. These five ships

have each given very good results so far as the machinery is concerned. The boilers are of the Belleville type, with the exceptions of the *Berwick* and *Suffolk*, in which the Niclausse design has been adopted. It should be, perhaps, interpolated here that the practice of adopting cylindrical boilers for one-fifth power was resorted to after the ordering of the ships comprised in Table I. It may be noted that in those cruisers the allowance of heating surface per indicated horsepower embraced in the design was about 2.29 square feet, while 13.65 indicated horsepower was to be realized per square foot of surface. The weight allowed for machinery averaged about 1,750 tons, so that 12½ horsepower had to be attained per unit of weight. This marks the highest results called for in recent design, and it is not too much to say that, without this limitation in weight, the high speed could scarcely have been realized. In the later cruisers of the *Duke of Edinburgh* class the weight has been considerably increased, the total for about the same power being 2,250 and 2,300 tons, which works out to about 10½ indicated horsepower per ton of machinery.

The trials of the *County* ships were carried through promptly and without trouble. It will be noted that the coal consumption on the low-power trial varied between 1.83 pounds and 2.1 pounds, while on the trial at about 16,500 indicated horsepower the rate ranged from 1.45 pounds to 2.22 pounds; at full power the consumption was at the rate of from 1.91 pounds to 2.22 pounds per unit of power per hour. Perhaps the most interesting fact about the later ships is that at 16,000 indicated horsepower they can maintain a speed of 22 knots. This is regarded as the speed which may be maintained so long as coal can be got from the bunkers; and, as the duration of the official trial at this power was 30 hours, it may be assumed that this performance ought to be maintained for an unlimited period, so far as the machinery and boilers are concerned. The Niclausse boiler ships, it will be noted, have low coal-consumption results on all three trials; but the *Monmouth*, with Belleville boilers, is quite as economical, which only shows again that one must not reason from the particular to the general.

The *Euryalus*, which comes next on our list, is one of the *Cressy* class, and her trials have been delayed, owing to an unfortunate accident in the dock, which can only be placed under that comprehensive phrase, "An act of God." Perhaps the interesting point of this ship is the apparent difference which increased displacement makes in the speed of a vessel. Here the power anticipated in the design was 21,000 indicated horsepower; but as the vessel displaced 12,000 tons, as compared with 9,800 tons in the case of the seven cruisers of the *County* class in the list, the speed, for almost the same power, was practically two miles per hour less. This vessel, however, is fitted with propellers having a smaller surface per unit of diameter; and as it has been found with the *Drake* class, as well as with the later *County* cruisers, that these large-surface and coarse-pitched propellers give better speeds, it may be assumed that part of the difference is attributable to the propeller. The next cruiser on the list—the *Challenger*—is, perhaps, interesting because it is the largest yet engined by the Wallsend Company. In this case the Babcock & Wilcox boiler was installed, and it will be seen that the coal consumption on all of the three trials averaged only 1.75 pounds per unit of power. Doubtless the Admiralty's satisfaction with the results had something to do with the awarding to the same company of a contract for machinery of 23,500 indicated horsepower, for the *Warrior*, recently laid down at the Pembroke Dockyard.

The *Clio*, which was fitted with Niclausse boilers, completes our list so far as new ships are concerned; but there is added to the table the results of the trials of the three gunboats, which have had new engines constructed by the Fairfield Company. These three gunboats were included in the Naval Defense Act fleet, and were launched about twelve years ago. They were originally fitted with boilers of the locomotive type, the power then developed being 3,500 indicated horsepower, with a speed of 19½ knots. Thornycroft steam generators have been substituted, and new engines of the four-cylinder triple-expansion type, of greater power, were installed, with the result that the full power was increased to 5,800 indicated horsepower, and the speed to

21¾ knots, the *Jason* coming out at 21.93 knots. This is an increase of 2½ knots to the speed for an addition of about 66 per cent. to the power.

Turning now to Table II, which gives the results of the trials of the torpedo-boat destroyers, it will be noted that nine vessels of this description are included. These ships were designed to attain a speed of 25½ knots, the scantlings of the hull being considerably strengthened as compared with the original 30-knot destroyers, while at the same time a high forecastle was added, so as to make the vessels more seaworthy. The result has been to increase the displacement of the boats from 300 or 330 tons to 540 or 550 tons, the length remaining at 225 feet, as compared with 210 feet to 215 feet. There has been a proportionate increase in beam. It has been necessary to develop from 7,000 to 7,800 horsepower in order to attain the speed, whereas 30 knots was got in some of the earlier destroyers for from 5,500 to 6,500 indicated horsepower. It will be noted that Messrs. Palmers have completed during the year the trials of three of these vessels; Messrs. Laird (of Birkenhead), of four, and Messrs. Yarrow, of two. The results are all set out in the table, and the reader will no doubt find there interesting matter for comparison. In three instances the coal consumption has exceeded 2½ pounds, and in this case, of course, the vessels had to carry a weight equivalent to this increased consumption during a four-hour trial. It is, perhaps, worthy of note that on the full-power trial the boilers—in the case of the *Itchen*, for instance—burned 72 pounds of coal per square foot of grate.

The trials of the *Velox* were of special interest, as she is fitted with Parsons turbines instead of ordinary reciprocating engines. This vessel, however, is considerably lighter than the destroyers to which we have just been referring, her displacement being only 440 tons, so that it is not possible to make any comparison as regards the results. None of our previous destroyers approximated to this displacement, but we are glad to note that the Admiralty have in contemplation a very exhaustive trial of this vessel, with a view of determining the steam consumption, and therefore the relative efficiency, of the turbine, as compared with

the ordinary piston engine, for such craft. Five of Thornycroft's torpedo boats are also included in the table. All of these vessels are of the same design, and it will be noted that the variations in speed are between 25.12 and 25.43 knots Curiously enough, this minimum and maximum speed was attained with practically the same power. The weather, or some other of the many variant conditions, might militate against speed, so that, however interesting such comparisons may be, they are more or less illusory.—"Engineering," Jan. 1, 1904.

THE CHILIAN BATTLESHIP *LIBERTAD*.

The following description of the Chilian battleship *Libertad* was prepared from information supplied to "Engineering" by authority of the Chilian Government, whose Naval Commission invited our representative to be present at all the trials in connection with the machinery, guns, etc., which were carried out before the purchase of the ship by the British Government.

It was known that in these vessels an effort had been put forth to secure the maximum of fighting efficiency on limited displacement and at reasonable cost. This limitation has been repeatedly urged as desirable by many responsible naval critics. There may be some reason in this contention, as there are many who feel that the steady advance in the size of British battleships, from the 14,000 tons of the *Royal Sovereign* of ten years ago to the 15,000 tons of the *Formidable*, the 16,350 tons of the *King Edward VII*, and the 18,000 tons of projected ships, involves too great a concentration of national capital, in view of the comparative ease with which such units may be rendered *hors de combat*, if not completely destroyed, by the torpedo stealthily fired from small, inexpensive craft. The cost of these immense ships has increased from the £900,000 of the *Royal Sovereign* to £1,426,000 for the *King Edward VII*.

The problem is, undoubtedly, one of extreme difficulty, because it is laid down that British ships of the line must be so designed as to combine all the necessary qualities to defeat each ship of any possible enemy, even if in the latter one element pre-

dominate at the expense of others. Thus every British ship of the line must be able to face a Russian ship, where gun power, and perhaps speed, excels, say, at the expense of protection; it must approach in speed the Italian vessel, where machinery has had a greater weight allowed than is usual in other ships; it must be able to maintain its position in combat against a French ship, in which the designer may have been allowed greater scope in the matter of armor than in the other elements. This has always been the contention, and no one will gainsay that this aim should be earnestly sought. But ideals are not easily attained in practice, and therefore a compromise must be introduced in order to get the best combination of qualities within those limits of dimensions which are imperative unless our harbors and docks are to be improved at great cost. Moreover, we have not the control of foreign waterways, which may become the venue of naval fights, and an opposing fleet, even locked up in a harbor of refuge, may prolong a war. This difficulty encourages the hope that the advent of the steam turbine may check the increase in beam, which is becoming serious, owing to the few docks in the world wide enough to accommodate existing ships of greatest beam. Further, there is always the bottom of the national purse to reckon with, and we are approaching limits in this respect, wealthy as our country is.

PRINCIPAL DIMENSIONS.

Length, feet	436
Breadth, feet	71
Draught, feet and inches	24–7½
Displacement, tons	11,800
Speed on measured mile, knots	19
Coal (normal), tons	800
(full), tons	2,000
Complement	700

ARMOR.

Water-line belt, inches	7, 6, 3
Citadel to upper deck, inches	7
Barbettes (fronts), inches	10
(rears), inches	8
Bulkheads, inches	6

Conning tower, inches	11
Protective deck, inches	1½, 3
Mild steel on bow, inches	2
Casemates (fronts), inches	7
(backs), inches, N.S	3

ARMAMENT.

Four 10-inch breech-loading guns.
Fourteen 7.5-inch breech-loading guns.
Fourteen 14-pounder quick-firing guns.
Four 6-pounder quick-firing guns.
Four pom-poms.
Four Maxim R. C. Guns.
Two 18-inch submerged torpedo tubes.
Two 12-pounder landing guns.

LIST OF BOATS.

56-foot vedette.
36-foot steam pinnace.
30-foot steam cutter.
42-foot launch.
32-foot sailing pinnace.
30-foot cutters (2).
32-foot gig.
30-foot gig.
27-foot whaler.
18-foot dingy.
Balsa raft.

Since every warship design is a compromise, we are forced to the question whether our official designs embody the best of combinations. The national confidence in our Admiralty administration is great, and rightly so, but there is the oft-repeated allegation that some of the foreign vessels designed and built by the great warship-building firms in this country are of relatively less weight, and yet embody qualities equal in the aggregate to those of British naval ships. In explanation of this, it is said that the cause of the greater displacement of the ships of our own Navy is to be found in the wide interpretation

placed on that comprehensive phrase, "Admiralty practice." We have heard that on one occasion, when the combatant officers of the Service were asked to make suggestions for battleship design, the resultant vessel would have been of prohibitive displacement had all their ideas been acted upon. It is just possible that the evil officially admitted in this case prevails to a greater or less degree in the preparation of the plans of all ships. We know that tradition and developments in science are often in conflict, and it too frequently happens that the claims of both are met by the simple, if expensive, method of duplication. Admitting that the British ship must contain and exhibit all the qualities to be found in her possible opponents, there is still the possibility that these may be attained by other conditions than those briefly described as "Admiralty practice." The *Libertad* and *Constitucion* were therefore looked upon with special interest; and this has been very materially intensified by the splendid performances achieved, not only on the steam and maneuvring trials, but also on the gun tests of the *Libertad*, as the vessels are now to be added to the British Navy. The official announcement of this fact was made subsequently to the preparation of our article, and we have thought it right not to alter in any way our comment upon the qualities of the two Chilian ships. We may interpolate here an expression of satisfaction at the Admiralty's commendable course in the purchase of these ships. There is the fact that these two battleships add appreciably to our sea power by reason of their splendid qualities, which place them high in the rank of our ships of the line, and make them the most effective ships for their size and cost in our Fleet.

The order for the *Libertad* was placed with Messrs. Vickers Sons & Maxim on February 26, 1902, and the condition of the contract was that the vessel should be completed ready for action on August 26, 1903, the time allowed being, therefore, 18 months.

There was every probability of the ship being built in the remarkably short time indicated in the contract. About that date, however, a permanent peace was ratified, and the necessity for

early delivery was greatly lessened, if not altogether overcome. The chairman of the company, speaking on the occasion of the launch, regretted the fact that there was no longer any incentive to rapidity of work, as he was anxious that there should be a practical demonstration of the immense advantage, so far as rapid construction was concerned, of the ordering of the ship complete for action in one contract from his firm, as against the British Admiralty method, under which separate contracts were made for armor, guns and ships, not necessarily even with the same company, and, as often as not, with little heed of the necessity for the simultaneous advance on each item to suit the general progress of construction. This latter surprising fact is explained by the circumstance that even such an important department as warship construction must adapt itself to the financial exigencies of the Treasury. Progress on the Chilian ships was very materially relaxed as the result of the peace; but, even so, the *Libertad* has been completed within two years from the date of the order, and within twenty-one months of the laying of the keel—a performance, which, notwithstanding it could have been improved upon, stands as one of which any establishment might well be proud.

The General Dimensions of the Ship.

In Table I, annexed, we give a comparison of the principal dimensions of some typical battleships, to show how the Chilian ship compares with others of even greater displacement. We have taken as representing the British Navy the *Russell* type, of which six vessels have recently been completed; the aim of their design being to so limit the displacement as to give a speed of nineteen knots, which was also the designed speed of the Chilian ships. The only smaller ship than the *Libertad* is the Austro-Hungarian vessel. From this table, and from an examination of the distribution of armor in the various ships, we think it will be seen that the *Libertad* compares well as regards armor protection. With the single exception of the Austro-Hungarian ship, the main guns of the ships named in the table are of greater caliber than is the case with the Chilian ship, but the

TABLE I.—COMPARISON OF "LIBERTAD" WITH SOME TYPICAL BATTLESHIPS.

	Chilian ship *Libertad.*	H. M. S. *Russell.*	French battleship *Patrie.*	Austria-Hungary : *Ersatz Laudon.*	German : *J. to M.*	Italian : *Vittorio Emanuelle III.*	Russian : *Orel.*
Length between perpendiculars...	436 ft.	405 ft.	439 ft.	390 ft. 6 in.	398 ft. 6 in.	435 ft. 6 in.	367 ft. 5 in.
Breadth.....	71 ft.	75 ft. 6 in.	79 ft. 6 in.	72 ft. 3 in.	73 ft.	73 ft. 6 in.	76 ft.
Draught.....	24 ft. 7½ in.	26 ft. 6 in.	27 ft. 6 in.	24 ft. 6 in.	24 ft. 10 in.	25 ft. 10 in.	26 ft.
Displacement.....	11,839 tons	14,000 tons	14,927 tons	10,600 tons	13,200 tons	12,624 tons	13,600 tons
I. H. P.....	14,090	18,000	18,000	14,000	16,000	20,000	16,000
Speed	20.17 knots	19 knots	18 knots	19 knots	18 knots	22 knots	18 knots
Armor belt.....	7 in.—6 in.	7 in.	11 in.—7in.—5½ in.	8 in.—5 in.	9 in.—4 in.	10 in.—4 in.	9 in.—4 in.
Armor gun position	10 in.—7 in.	11 in.—6 in.	12½ in.—6 in.	8.2 in.—4 in.	10 in.—6 in.	8 in.	10 in.—4 in.
Armament	4 10-in. 14 7.5-in. 14 14-pdrs. 2 12-pdrs. 4 6-pdrs. 4 1-pdrs. (pom-poms) 4 R. C. Maxims	4 12-in. 12 6-in. 12 12-pdrs. 6 3-pdrs. ...	4 12-in. 18 6.4-in. 26 3-pdrs. 2 1-pdrs. ...	4 9.4-in. 8 7.5-in. 6 6-in. 28 smaller ...	4 11-in. 14 6.7-in. 12 3.4-in. 12 1.4-in. 8 R.C. Maxims	2 12-in. 12 8-in. 12 3-in. 12 1.8-in. ...	4 12-in. 12 6-in. 20 3-in. 20 3-pdrs. 6 1-pdrs.
Approx. weight of projectile per min.	13.5 tons	8.9 tons	9.9 tons	8.8 tons	10.25 tons	8.7 tons	9 tons
Approx. collective muzzle energy.....	1,705,249 ft.-tons	984,365 ft.-tons	1,073,308 ft.-tons	764,042 ft.-tons	1,011,462 ft.-ts	643,861 ft.-ts	784,295 ft.-ts
Approx. energy at 3,000 yards range..	850,243 ft.-tons	822,596 ft.-tons	499,837 ft.-tons	376,203 ft.-tons	536,881 ft.-tons	275,899 ft.-ts	307,868 ft.-ts

TABLE II.—COMPARISON OF THE "LIBERTAD" WITH CRUISERS OF APPROXIMATELY SIMILAR SIZE.

Particulars.	Chilian Battleship *Libertad.*	British: *Cressy* Class.	British: *Diadem* Class.	French: *Léon Gambetta.*	German: *Deutschland.*	United States: *Tennessee.*	Russian: *Bayan.*
Length	436 ft.	440 ft.	435 ft.	480 ft.	403 ft.	502 ft.	443 ft
Breadth	71 ft.	69 ft. 6 in.	69 ft.	70 ft. 3 in.	65 ft. 6 in.	72 ft. 9 in.	55 ft. 9 in.
Draught	24 ft. 7½ in.	26 ft. 3 in.	25 ft. 3 in.	26 ft. 3 in.	24 ft.	25 ft.	22 ft.
Displacement	11,839 tons	12,000 tons	11,000 tons.	12,550 tons	9,350 tons	14,500 tons.	7,800 tons
Indicated horsepower	14,090	21,000	18,000	27,500	18,500	25,000	17 400
Speed	20.17 knots	21 knots	20¾ knots	22 knots	21 knots	22 knots	22 knots
Type of boiler	Yarrow	Belleville	Belleville	Niclausse	Dürr	Water-tube	Water-tube
Coal (normal)	800	800	1,000	1,350	950	900	750
(full)	2,000	1,600	2,000	2,100	1,500*	2,000	1,100
Armor and protection.							
Water-line belt	Complete 7-in., 6-in. and 3-in.	Partial 229 ft. 6 in. 6-in.	Nil	Complete 6-in.—4-in.	Complete 4-in.—3½ in.	Complete 6-in.—3½-in.	Partial 8 in.—3 in.
Armored gun citadel	232 ft. long, 7 in.	Nil	Nil	Nil	Small redoubt 4 in.	5 in.	3 in.
Barbettees to large guns	10 in.	6 in.	Nil	8 in.	6 in.	9 in.—8 in.	7 in.
Casemates	7 in. fronts, 3 in. rears.	5 in. fronts, 2 in. rears	6 in. fronts, 2 in rears	4 in.	Nil	5 in.	3 in.
Conning tower and tube	11 in. 8 in.	12 in. 7 in.	12 in. 7 in.	8 in.	6 in.	5 in.	
Protective deck	1½ in.—3 in.	1½ in.—3½ in.	2½ in.—4 in.	1½ in.—2½ in.	1½ in.—3 in.	1½ in.—3 in.	2 in.
Armament	4 10-in. (45 cal.) 14 7.5-in. (50 cal.) 14 14-pdrs. 2 12-pdrs. 4 6-pdrs. 4 1-pdrs. 4 R.C. Maxims 2 18-in. submerged tubes	2 9.2-in. 12 6-in. 14 12-pdrs. 3 3-pdrs. 8 R.C. Maxims 2 18-in. submerged tubes	16 6-in. 14 12-pdrs. 3 3-pdrs. 8 R.C. Maxims 2 18-in. submerged tubes	4 7.6-in. 16 6.4-in. 22 3-pdrs. 2 1-pdrs.	4 8.2-in. 10 5.9-in. 12 3½-in. 10 1-pdr. 4 machine guns	4 10-in. 16 6-in. 22 3-in. 12 3-pdrs. 4 1-pdr. 8 machine guns	2 8-in. 8 6-in. 20 2.9-in. 7 1.8-in. 5 torpedo tubes.

* Also liquid fuel.

fourteen 7.5-inch guns give her a great advantage over the secondary armament of any of the other ships, while in the matter of smaller guns, for repelling attack by small craft, she far excels. We have added a statement showing the approximate weight of projectiles which may be fired per minute, taking the nitro-cellulose results of the Chilian ship, as well as of other vessels using this compound. The total weight of one minute's fire is 13½ tons. Taking the primary guns only, the minute's fire is:

	Lbs.	Lbs.		Foot-tons in energy.
12 projectiles of	500 =	6,000	and	335,568
98 projectiles of	200 =	19,600	and	1,186,754
110		25,600		1,522,322

From each broadside there may be fired per minute 12 protiles of 500 pounds and 49 of 200 pounds—a total of 15,800 pounds, with an energy of about 928,943 foot-tons. When chasing the enemy this Chilian ship can fire ahead each minute six projectiles of 500 pounds and 28 of 200 pounds, in all 8,600 pounds, with a collective energy of about 506,855 foot-tons. The vessel has also an immense gun power against torpedo or submarine boat attack. Her smaller guns fire per minute 280 projectiles of 14 pounds, 112 of 6 pounds, 1,200 of 1 pound (pom-poms) and 2,400 rifle bullets, so that the enemy, once discovered, would have little chance of escape.

The comparison given in the table of the approximate weight of projectiles which may be fired per minute under the best conditions, and of the resultant collective energy, is interesting, although it cannot be accepted as obtainable under all conditions, or for any definite period of time; it is really the highest possible standard. It will be seen that the Chilean ship comes out far ahead of any of the others.

The *Libertad* has been regarded in some quarters as more representative of an armored cruiser, although we think this is without sufficient justification; but in view of this we have prepared a comparison, which is given on Table II, of the dimensions and fighting qualities as compared with typical armored

cruisers. It will be seen that the Chilian battleship *Libertad* has lost a little in speed, being from half to one and three-quarter knots slower than the armored cruisers mentioned; but that she is equal to the best in coal capacity, and her armor protection is very considerably superior, esp ecially in the matter of protection of armament. In the matter of gun power she is, of course, far in excess; indeed, taking her main armament, it may be said that it is about double the power, either in maximum individual shot or collective energy, of any of the ships on the list; while her smaller guns are more than double, in effect, those of any of the other ships named in the table.

The Hull.

The ship is built with a double bottom under the magazines and machinery spaces, which extend through 285 feet of the total length; forward and abaft this the construction is continued, as in British ships, with watertight flats extending to the bow and stern; so that with these there is practically the advantage of an outer and inner shell from end to end. The depth between the two bottoms is 3 feet 6 inches under the magazine and boiler spaces, and 7 feet 6 inches under the engine space. The total length of the machinery space is 140 feet. The cellular construction, it will be noted, extends to the protective deck. The framing consists of heavy channels at 4-foot intervals. The protective deck extends through the whole length of the ship, and slopes down at the sides to the lower edge of the broadside belt, forming there the usual shelf for the armor. The thickness of this protective deck within the citadel, forward and abaft the armored bulkheads, is 3 inches.

The interior of the ship under this protective deck is well divided into watertight compartments by transverse and longitudinal bulkheads and flats. Even above the protective deck the interior of the ship is largely separated into compartments.

Armor Protection of the Ship.

In these new battleships the proportion of displacement given up to armor protection is about 17.5 per cent., while in re-

cent British ships it averages 14 to 15 per cent., having decreased slightly as the process of hardening the surface of the plate has been perfected, although at the same time the naval architect has utilized some considerable part of the weight saved for a given power of resistance in order to increase the area of protection.

Instead of applying the scattered casemate system for protecting quick-firing guns, as in previous battleships, the Vickers company adopted a unique arrangement under which the guns are concentrated within the central battery, so that there is no unarmored space on the broadside between the casemates. Such unprotected sides, where existing, may in action admit projectiles to the interior of the ship, where considerable damage might result to the comparatively unprotected rear of the casemate guns on the other side of the ship. The new arrangement procures a combined advantage of complete isolation for each of the 7.5-inch guns, along with a continuous armor-plated side for the full above-water depth of the ship throughout a great part of the length, thus ensuring an armored reserve of buoyancy and stability.

The protection of the British battleship of the *King Edward VII* class is arranged on the same principle, and the *Libertad* is also designed on the "concentrated casemate" system.

The broadside armor extends from 4 feet 6 inches below the waterline to the upper deck, a depth in all of 21 feet. This depth and thickness extends over 195 feet of the length of the ship; but forward of this there is a continuation to the ram of a water-line plate, 8 feet deep—3 feet 6 inches above and 4 feet 6 inches below the load waterline, part of it being 6 inches thick and part 3 inches, while at the ram it is 2 inches. Abaft the citadel the armor is continued, first with a thickness of 6 inches and then of 3 inches, right to the stern.

There is at each end of the citadel a protective screen bulkhead of 6 inches in thickness, affording protection against raking fire.

The barbettes are circular in shape, and the armor is 10 inches in thickness in the front and 8 inches at the rear. There

are transverse and longitudinal protective bulkheads separating the 7.5-inch gun positions within the citadel. There is a conning tower under the main bridge constructed of 11-inch armor. The four casemates for the 7.5-inch guns on the upper deck are of 7-inch armor in front and 3-inch in the rear.

The Armament of the Ship.

The *Libertad*, for her size and displacement, is the most powerfully-armed ship yet constructed. She carries four 10-inch guns mounted in pairs in barbettes forward and aft, already described so far as their armor protection is concerned. It is, however, in the secondary armament that the *Libertad* excels. In our British battleships, up to those designed subsequently to the Chilian vessels, the secondary armament, in addition to the 12-inch guns, consisted entirely of 6-inch weapons, but in these Chilian ships, fourteen 7.5-inch guns, 50 calibers long, have been installed, five on each broadside in the concentrated casemate or citadel, and four of them, one each in a separate casemate, at the four corners of the citadel on the upper deck. These 7.5-inch guns are more than double the power of the 6-inch weapons, a fact which largely explains the superiority of the *Libertad* as compared with ships of her own class, as indicated in Table II.

The Hydraulic Power for Working Guns.

Two sets of pumping engines are employed for supplying the hydraulic power for working the guns and other purposes. These pumps are of the compound-tandem type, each pair of cylinders being coupled up direct to the pump ram of a double-acting pump. Each engine is of sufficient power to fulfil the maximum requirements of both turrets, the other engine remaining as reserve. The steam pressure in the cylinders does not exceed 150 pounds per square inch, and the engines exhaust into the atmosphere or into a closed exhaust pipe. The parts are, however, designed to stand the full boiler pressure of 300 pounds per square inch. The engines are constructed so as to admit of ready examination of all working details, and are capable of maintain-

ing, if required, unloaded, a uniform speed of three revolutions per minute. This is effected by means of speed and pressure governors, arranged to control a steam throttle valve on the high-pressure cylinders. These governors also maintain automatically an approximately uniform working pressure in the system, and will likewise prevent the engines from racing should the pressure fall abnormally low, owing to the bursting of a pipe or other cause. A relief valve for each engine is fitted on the hydraulic supply near to the pump, loaded to something slightly in excess of the working pressure of the system, so that when the engines are moving round dead slow, and no water is required by any of the various hydraulic machines in the ship, the water will pass through this relief valve to the suction side of the pump.

The high-pressure slide valves are of piston type, but the low-pressure are ordinary D slides with a balance ring on the back of each to relieve the pressure. The cylinders, valves, casings and passages are all arranged to be practically self-draining. The piston and piston valves are fitted with cut packing rings with free ends. These rings are of hardened bronze and have their outward movement restricted in the manner which is now usual. Relief and drain valves and pipes are fitted at each end of the cylinders, receivers and pumps; they are arranged conveniently to drain into a "save-all" placed below the engines. Turning gear is provided, so that when in harbor the engines may be turned round easily by one man. Sight-feed lubricators are fitted on the main steam pipes, and all moving parts are provided with an efficient water service. The cylinders and covers, slide-valve casings and covers, are completely clothed with incombustible non-conducting material, covered with planished sheet steel secured with brass screws.

The tanks for the necessary supply of water for these engines are built into the structure of the ship, and are fitted with strainers, gauge glasses, air valves, and combined air and relief valves. The whole of the water-pressure and exhaust pipes are solid-drawn, and made of copper and manganese-bronze, the latter material being used for pressure pipes over 1 inch in diameter. The water pressure in the system is 1,000 pounds per square

inch. The main pressure pipes inside the turntable are arranged on the ring system, the connection between the pressure pipes inside the turntable and those outside being effected by means of a system of jointed pipes, which are at all times readily accessible, and capable of being renewed.

Guns for Repelling Torpedo Attack.

The Chilian ships undoubtedly excel anything afloat, so far as the installation of guns for the repulsion of torpedo and submarine-boat attack is concerned. In the *Libertad* there are fourteen 14-pounders. The disposition of these guns is four—two on each side—on the upper deck, in the waist of the ship, and two right forward and two aft on the main deck. Well over the casemates—therefore at very high level—there are four more, the remaining two being placed under the navigating bridge. In addition, there are four 6 pounders on the boat deck, and commanding a very good view of the surrounding water. On each of the military tops there are two pom-pom guns, whereas in British ships the practice has been to fit here only Maxims. There are, also, two 12-pounder guns, used principally for landing service, and also four Maxim guns; these are placed two on the aft bridge and two on the forward bridge.

The Ventilating Arrangements.

With respect to the ventilation of the vessel, no great difference exists between the system as adopted for the *Libertad* and that which obtains at present in the British service, excepting the greater number of electrical fans supplied for the more efficient ventilation of the various compartments, and the effort which has been made to keep the ventilation of each compartment independent as far as possible, and thus in a great measure to maintain the integrity of the bulkheads throughout the vessel. This artificial ventilation, by means of electrical fans, has been rendered possible by the great reserve of electrical power possessed by the *Libertad*.

The coal-bunker ventilation has been kept quite distinct from that of the general system, and care has been taken in so arrang-

ing the whole of the ventilation that the armored deck has been perforated as seldom as possible; and wherever openings have been pierced in such deck, provision has been made so that the aperatures can be opened or closed from the weather decks, while automatic valves are arranged so as to readily close in case of fire.

The ventilation of the magazines forms yet another separate system, and follows very closely the British Admiralty practice, special provision being made for thoroughly ventilating the barbettes, and for driving smoke and powder gases out of such places during action.

Electrical Equipment.

As regards the electrical equipment, this is arranged on a more elaborate scale than that usually adopted in British ships, and the use of incandescent lamps throughout the vessel is most complete. The total number of lamps is about 1,000, generally of 16-candlepower, with 50-candlepower lamps in clusters on the yard arms, and lamps of 50-candlepower for the coal bunkers.

There are five dynamos in the vessel, each of 500 ampères at 100 volts, when running at 400 revolutions, together with the necessary engines, these dynamos being all coupled up to the switchboard by specially insulated cables. The switchboard is suitable for parallel running, is capable of dealing with the total number of dynamos and circuits required, and fitted in a position adjacent to the dynamos, easily accessible and convenient as regards manipulation of switches and other necessary work at the switchboard.

The circuits are distributed by means of specially insulated cables to gun-metal section boxes, which boxes feed the watertight distributing or cut-out boxes, from which the lamps are controlled. In addition to the above, there is a rotary transformer, the whole being arranged so that the complete electrical equipment is entirely under the manipulation of one engineer.

Five powerful searchlights of a special pattern are fitted, and generally arranged so that they can be withdrawn into cover during action or stress of weather. All the projectors are pro-

vided with automatic feed lamps and mirrors on the Mangin principle.

In addition to the electric-lighting plant, named above, there are about 70 electric motors in the vessel generally for ventilating purposes, but electric ammunition hoists are also arranged for the 7½-inch guns, and, wherever suitable, electrical power has been applied so as to reduce, as far as possible, manual labor on board.

The Drainage System.

A great feature in the design of the *Libertad*, is the very complete and efficient system for the pumping, draining and ventilation of the ship, whereby any single compartment can be at once drained, and a sufficient quantity of fresh air admitted to keep every place perfectly ventilated. This has been arranged without the usual duplication, and yet it is in all respects capable of the highest efficiency. The pumping power alone is enormous. In addition to the ordinary circulating pumps fitted in the engine rooms, and connected to the main drainage system of the vessel, there is one double-cylinder bilge and fire engine of duplex type fitted in each engine room, with cylinders 7½ inches in diameter, arranged so as to be capable of pumping from the sea, bilges and crank pits, and to discharge into the fire mains, on deck or overboard. Two double-cylinder engines of duplex type, with cylinders 7½ inches in diameter, are also fitted above the water line, to be used for fire and other purposes. Special engines are fitted for pumping out the crank pits. For the distribution of fresh water to the various compartments, 4½-inch pumps are fitted in convenient positions.

The whole drainage system has been arranged so as to effectually clear every compartment in the vessel, care being taken that all the main bulkheads should be pierced as seldom as possible; and although arrangements have been made for drawing water from each compartment, where such compartments are so small as not to endanger the safety of the vessel through flooding, duplicate independent suctions, leading direct to the Downton pumps, have not been fitted, and thus a multiplicity of sluice and other valves has been dispensed with, while still ensur-

ing a complete and efficient service. Wherever possible and desirable a system of drainage from the smaller compartments into the larger and main compartments has been arranged in preference to an independent suction; and here again there is a great saving, not only of weight, but of labor in working.

Notwithstanding that every endeavor has been made to drain the smaller compartments rather than to fit independent suctions, great care has been taken to so arrange the general cementing that the lead of water to the various pumps and suctions should be efficient without the introduction of a large weight of cement.

The Propelling Machinery.

The propelling machinery consists of two sets of inverted triple-expansion engines, each set having four cylinders. Each cylinder works its own crank, and all are balanced on the Yarrow, Schlick and Tweedy system. The engines are placed in separate compartments, divided by a middle-line bulkhead. The high-pressure cylinders are 29 inches, the intermediate 47 inches and the low-pressure 54 inches in diameter, with a stroke of 39 inches. All the cylinders are separate castings, and are not connected by steam joints, so that they follow in this respect the practice of the British Admiralty. All the cylinders are steam jacketed. They are supported at the front by six forged-steel columns and at the back by four cast-iron columns. Each pair is bolted together at the back and front, and stays are fitted athwartship between the cylinders and the center-line bulkhead.

Steel pistons are fitted in all the cylinders, the packing rings being of the restricted form in the high-pressure and intermediate, and of the deep single-ring type in the low-pressure cylinders, and held in place to the bore of the cylinders in the latter case by steel spiral springs. Steam is distributed to the high-pressure and intermediate cylinders by piston valves; double-ported slide valves, with balance rings for reducing the pressure on the valve face, are fitted to the low-pressure cylinders. The valve gear is of the double-bar link type, all working parts being made adjustable for wear, and provided with ample rubbing surface. The reversing shaft, which is placed at the back

of the engines, is carried on cast-steel brackets; the reversing levers are of forged steel. The reversing engine, which is of the two-cylinder type, is neat and compact, and is fitted on one of the front columns, the shaft being extended to drive a gun-metal worm wheel, working on a pin on one of the back columns. Provision is made for reversing by hand as well as by steam.

All the working parts are of forged steel. The main bearing frames are six in number, and are of cast steel, fitted with gun-metal bushes lined with white metal, the keeps for the bearings being of forged steel.

The thrust-block is of the horseshoe type; the propeller shafting is 13½ inches in diameter. The stern tubes are bushed with gun metal at the forward end, and at the after end and "A" bracket with lignum vitæ. The bushes are in halves. The four propeller blades in each screw are of bronze, and the bosses are of gun metal.

Turning now to auxiliaries, we have, first, an air pump, 25 inches in diameter and 19 inches stroke, driven by means of links and levers from each of the high-pressure crossheads. The low-pressure cylinders in each engine room exhaust into a cast gun-metal condenser, having a cooling surface of 6,250 square feet. The condenser tubes are ⅝-inch in external diameter and 0.048 inch thick. There is one main circulating pump for each set of engines, which can be utilized for pumping to either condenser, and from bilge in case of emergency. Separate double-cylinder turning engines are fitted to each set of engines.

The following auxiliaries are also placed in the engine rooms: Two auxiliary condensers, two auxiliary air and circulating pumps, two fire and bilge pumps, four evaporators and pumps and two distillers; two grease extractors of the gravitation type, two crank-pit pumps, two ventilating fans in casing on protective deck, and also two additional fire pumps on this deck. Feed tanks of ample size are built into the wings of the engine rooms.

There is a very efficient workshop, which is fitted with a doube-cylinder steam engine, one lathe, two drilling machines, one grindstone, one punching and shearing machine, one planing and shaping machine and the usual vises, lockers, &c.

There are also separate rooms for storing the smaller spare parts.

THE BOILERS.

There are twelve boilers in the ship, all of the Yarrow large-tube type, and these are arranged in four water-tight compartments. Most of the boilers were made at the Barrow Works, but some were constructed by Messrs. Yarrow. Each stokehold forms a separate watertight compartment, and is fitted with feed pumps, fans, ash ejectors and ash hoists. The two funnels are 10 feet 6 inches in diameter over the casings, the height from the fire grate being about 90 feet.

Each boiler is capable of developing about 1,200 horsepower. The weight of each boiler complete with water is 34½ tons and without water about 29 tons. The boilers were made for a steam pressure of 280 pounds. There are 1,008 tubes in each boiler, 1¾ inches outside diameter and $\frac{5}{32}$ inches thick, except the two rows nearest the fire, which are $\frac{9}{16}$ inches thick. The average length of the tubes is 6 feet 9¼ inches, and each tube is expanded into the tube plates and bell-mouthed at both ends. One row of distance pieces is fitted to each nest of tubes to maintain a uniform distance apart between them. Each boiler has a heating surface of 3,127 square feet.

The following are the particulars of the boilers in the *Libertad*:

Number of boilers	12
Total heating surface, square feet	37,524
Total grate area, square feet	664
Ratio of heating to grate surface	56.5 to 1
Indicated horsepower per square foot of grate	21.22
Heating surface per unit of power, square feet	2.66

Experiments were carried out to compare the economy of one of the boilers with two different sizes of grates, in both cases burning approximately the same total quantity of coal, giving different rates of combustion per square foot of grate. On these tests the working pressure was 230 pounds. These experiments were made by Messrs. Marriner and McQueen, and the results were embodied in a paper read before the Junior Institution of Engineers. As they are of considerable interest, we may quote the following:

The boiler on the first trial had a grate area of 53 square feet; on the second the area was 40 square feet. The duration of both trials was twenty-four hours. The original dimensions of grate were 7 feet 9½ inches wide by 6 feet 10 inches long, and were reduced to 6 feet 11 inches wide by 5 feet 9½ inches long.

In the data given in Tables V and VI* the water evaporated per pound of coal is brought down to a common standard from and at 212 degrees Fahrenheit. The fire was forced by means of a jet of steam in the funnel, as in the case of locomotives. The partial vacuum thus produced was measured by the difference of level of water in a U tube, one end of which led into the uptake, the other end being open to the atmosphere. Looking at Table V, the data for the first trial—that is, with the larger grate area of 53 square feet—it will be observed that during the first hour 2,240 pounds of coal were put on the bars; during the second hour 1,456 pounds, and so on. During the fifteenth hour only 896 pounds were put on, because the fire was cleaned after the end of that hour, and the amount of coal put on the bars was intentionally reduced, so that nearly all might be burnt before the cleaning of the bars took place. When the fire was restarted, a considerable quantity of fresh coal had to be put on for the sixteenth hour, which accounts for the apparent extra coal consumption during that hour. It must therefore be noted that this column does not represent the amount of coal consumed in each hour, but the amount put on the bars during each hour. In the next column the total number of pounds of coal used from the commencement of the trial is given. The next column gives the amount of water evaporated each hour: for instance, during the first hour 14,350 pounds of water were evaporated. In the eighth column the total water evaporated is given from the commencement of the trial. In the next column is shown the quantity of water evaporated per pound of coal from and at 212 degrees Fahrenheit, the figures in every case in this column starting from the commencement of the trial; and the next column gives the mean air pressure for each hour, which, you will observe, gradually increases up to the point when the fire is cleaned, the reason for this being that as the clinker forms, the

*See pages 288 and 289 for these tables.

passage for the air through the fire becomes more and more restricted. Immediately after the fire was cleaned, and the grate unobstructed from clinker, the air pressure fell. It will be seen from this that during the twenty-four hours 37,856 pounds of coal were burnt and 306,550 pounds of water evaporated, which works out to 9.96 pounds as the average quantity of water evaporated per pound of coal from and at 212 degrees Fahrenheit.

On the second trial, with the grate area of 40 square feet, similar observations were taken. By reference to Table VI it will be seen that the total coal burnt during the 24 hours was 37,744 pounds, which is nearly the same as that consumed during the first trial. The quantity of water evaporated was 325,650 pounds, which works out to a mean of 10.57 pounds of water evaporated per pound of coal, from and at 212 degrees Fahrenheit, as compared with 9.66 pounds of water evaporated in the former case; so there is evidently a distinct advantage in favor of the smaller grate area under these conditions of trial, with Welsh coal of moderate quality. The mean air pressure with the larger grate was 0.56 inches, and with the small grate 0.75 inches.

The air pressure increases up to the point when the fire is cleaned; and after the fire is cleaned and the clinker removed, it suddenly drops. The same total amount of air being required with both grates accounts for the air pressure being higher with the smaller grate.

In both cases a sudden drop will be noticed at the time of cleaning the fire, preceded by a rather higher apparent efficiency. This drop is due to the extra quantity of coal put on after the cleaning of the bars, and, in consequence, not so much was apparently evaporated per pound of coal for that hour. Before the cleaning, however, the quantity of coal put on the fire was reduced, which accounts for the higher apparent efficiency during that hour. It will also be observed that there is a rather sudden drop during the seventh hour, which is prbably due to the fire getting too thick, the effect of faulty stoking.

It will be noticed that the advantage in economy of the small grate is maintained to the end of the trial. Some people attrib-

ute the greater evaporative efficiency of the small grate, with its more intense combustion, to the gases being burnt more quickly and not being so likely to come into contact with the cold surface of the tubes in an unburnt state, extinguishing the flame in the same manner as the wire gauze which surrounds a Davy lamp, as may be the case with the larger grate and more sluggish combustion.

For convenience in stoking, the small grate is decidedly more advantageous, as a smaller area has to be watched and covered with fuel; also the amount of floor area—which, of course, is an important item in warships—is so frequently limited that a small grate is an additional advantage.

As regards the machinery in the four boiler rooms, it may be said first that the closed stokehold system of forced draft is adopted, and the air is supplied by means of eight steam-driven double-breasted fans, 72 inches in diameter.

There are one main and one auxiliary feed pump in each boiler room; the auxiliary pumps are arranged to supply any of the twelve boilers. One ash ejector is fitted to each boiler room, and two pumps—one each in No. 2 and No. 4 stokeholds. There are two air compressors for supplying air for cleaning boiler tubes from soot. In addition to the ash ejectors, one steam ash-hoist engine is fitted to each stokehold, together with means for hoisting ashes by hand. The main steam pipes are of steel. A steam-pipe separator is fitted in each engine room, having a hand and automatic blow-off to condensers. No automatic feed regulators are fitted to the main boilers, the check valves being regulated from the stokehold floor.

Trials of the "Libertad."

The trials were carried out under strict supervision and to the very letter of the contract.

On Saturday, November 28, 1903, the vessel was taken through the first test required under the contract—namely, the progressive speed trials, which trials, in addition to supplying the shipbuilders with valuable data for future designs, are of great use to the officers responsible for arranging the speeds at which the vessel

is to be run under varying conditions of service. At 12 knots it was found that the average of the revolutions was about 90, and that less than a sixth of the total indicated horsepower was being used. The next run increased the speed by about 3 knots, or 25 per cent., but it more than doubled the power, whilst another 2½ knots gave additional power equal to, approximately, 80 per cent. The runs at full power gave a mean speed of 20.17 knots, with an indicated horsepower of 14,090 and 158 revolutions of the engines.

In addition to the above trial, according to the terms of the contract, a long-distance run had to be made, such run not to exceed 48 hours. During this run of 27 hours a mean speed of 17¼ knots was obtained; everything worked well, and the twelve Yarrow water-tube boilers fitted on board gave every satisfaction; whilst the coal consumption worked out for the whole trial and for all purposes at 1.71 pounds per indicated horsepower per hour. Notwithstanding the severe test to which the vessel had been put, so confident were the directors of Messrs. Vickers in the capabilities of the ship, that they at once decided to have a short run at full power, and the result proved that their confidence was not misplaced. For about two hours the vessel ran over the measured mile at Skelmorlie, when a speed of about 19½ knots was obtained; and this, it should be taken into consideration, was with the furnaces working under adverse conditions as compared with the usual speed-trial arrangements.

The next test was the contract stipulation that the vessel should make at least six runs over the measured mile at her full power, so that reliable information might be obtained as to her highest speed. It was decided, so that there should be no question as to the draught and trim of the vessel when on trial, that the vessel be loaded down to a mean draught of 24 feet 8 inches. This necessitated placing the weights so that the center of gravity, both in the vertical and longitudinal positions, should be practically coincident with those of the vessel in her equipped condition with all stores, crew, ammunition and coal on board; and her initial stability, or height of metacenter above the center of gravity, was identical with what it would be in service.

After weighing anchor, the engines were started slowly, and the vessel headed out to sea, allowing the engines gradually to work up to full speed, until, at 8·38 A. M. on Friday, December 4, the six-hours' full-speed trial was commenced, the engines then running at about 150 revolutions per minute. During this trial there was a strong westerly wind and a choppy sea. Six runs were taken over the measured mile at Skelmorlie, and the mean speed of these runs was 20.17 knots, with a mean of 158 revolutions per minute, and an indicated horsepower of 14,090. As the contract specified that the trial at full speed had to continue for six hours, the vessel was, on the completion of the measured-mile trials, headed out to sea to continue this trial, when a speed of 20.12 knots, and an indicated horsepower of 14,000, were obtained, with an average coal consumption of 1.73 pounds per indicated horsepower per hour.

Before leaving the question of speed trials attention must be drawn to the admirable results obtained. A comparison of the speeds and powers for the battleships and cruisers, given in separate tables in the present article, will at once show the great disparity which exists between the performance of the *Libertad* and the performance of somewhat similar ships in other navies; and inquiries addressed to the builders as to why such discrepcies should exist have drawn from them the statement that they consider the lines of the *Libertad* as being probably the best possible that could be arranged on the dimensions and for the speed, whilst the efficiency of the machinery and propellers is the maximum which could reasonably be expected for the present system of propulsion. They claim to have in the *Libertad* obtained an actual propulsive efficiency of about 0.6.

It will be noticed that at a speed of 19 knots, with her full coal supply, she would be able to cross the Atlantic, having still a reserve of coal for emergencies, whilst at a speed of 10 knots her radius of action is about 12,000 knots.—"Engineering."

TABLE V.—EVAPORATIVE TRIAL OF ONE BOILER (YARROW TYPE) FOR CHILIAN BATTLESHIP: HEATING SURFACE, 3127 SQUARE FEET; GRATE AREA, 53 SQUARE FEET.

Number of hour.	Time at end of hour.	Coal during hour.	Coal per sq. ft. of grate area per hour.	Total coal.	Water during hour.	Water evaporated per lb. of coal per hour from and at 212° F.	Total water.	Total water evaporated per pound of coal from and at 212° F.	Air pressure. Inches of water.	Remarks.
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs*	*lbs.*	*lbs.*		
1	8 A. M.	2,240	42.30	2,240	14,350	7.88	14,350	7.88	.26	Steam blowing off at 230 lbs. above atmosphere.
2	9 A. M.	1,456	27.45	3,696	12,600	10.65	26,950	8.98	.17	
3	10 A. M.	1,624	30.6	5,320	13,000	9.84	39,950	9.23	.23	
4	11 A. M.	1,568	29.6	6,888	14,750	11.58	54,700	9.77	.26	
5	Noon	1,680	31.7	8,568	15,700	11.50	70,400	10.10	.32	Mean temperature of feed, 47° F.
6	1 P. M.	1,792	33.8	10,360	14,900	10.22	85,300	10.12	.33	
7	2 P. M.	1,400	26.4	11,760	12,150	10.69	97,450	10.20	.30	
8	3 P. M.	1,960	37.0	13,720	10,800	6.78	108,250	9.70	.34	
9	4 P. M.	1,344	25.4	15,064	9,600	8.79	117,850	9.61	.33	
10	5 P. M.	1,176	22.2	16,240	9,400	9.83	127,250	9.63	.35	
11	6 P. M.	1,232	23.2	17,472	10,550	10.52	137,800	9.70	.58	
12	7 P. M.	1,568	29.6	19,040	12,150	9.54	149,950	9.70	.84	
13	8 P. M.	1,568	29.6	20,608	12,350	9.68	162,300	9.68	.85	
14	9 P. M.	1,176	22.2	21,784	12,150	12.71	174,450	9.85	.96	
15	10 P. M.	896	16.9	22,680	10,400	14.26	184,850	10.03	.95	
16	11 P. M.	1,848	34.9	24,528	10,000	6.65	194,850	9.78	.24	Cleaned fire.
17	Midnight	1,624	30.6	26,152	14,450	10.93	209,300	9.85	.37	
18	1 A. M.	1,568	29.6	27,720	12,550	9.85	221,850	9.85	.32	
19	2 A. M.	1,568	29.6	29,288	11,700	9.18	233,550	9.81	.33	
20	3 A. M.	1,624	30.6	30,912	14,500	10 98	248,050	9.87	.77	
21	4 A. M.	1,680	31.7	32,592	14,600	10.69	262,650	9.92	.98	
22	5 A. M.	1,512	28.5	34,104	13,900	11.31	276,550	9.97	1.10	
23	6 A. M.	1,848	34.9	35,952	13,800	9.19	290,350	9.94	1.23	
24	7 A. M.	1,904	35.9	37,856	16,200	10.46	206,550	9.96	1.07	

Average evaporation from and at 212 degrees Fahrenheit during 24 hours = 9.96 pounds.

TABLE VI--EVAPORATION TRIAL OF YARROW BOILER FOR CHILIAN BATTLESHIP: GRATE AREA, 40 SQUARE FEET.

No. of hour.	Time at end of hour.	Coal during hour.	Total coal.	Water evaporated each hour, feed 47 degrees Fahr.	Total water evaporated.	Average water evaporated per pound of coal from and at 212 degrees Fahrenheit.	Air pressure, inches of water.	Remarks.
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*		
1	8 A. M.	1,792	1,792	14,000	14,000	9.6	.3	Steam blowing of at 230 lbs.
2	9 A. M.	1,568	3,360	13,600	27,600	10.09	.35	above atmosphere during
3	10 A. M.	1,568	4,928	15,350	42,950	10.71	.4	entire trial.
4	11 A. M.	1,736	6,664	15,100	58,050	10.70	.48	Mean temperature of feed,
5	Noon.	1,512	8,176	15,000	73,050	11.00	.48	47 degrees Fahrenheit.
6	1 P. M.	1,624	9,800	13,350	86,400	10.83	.5	
7	2 P. M.	1,344	11,144	13,050	99,450	10.98	.65	
8	3 P. M.	1,568	12,712	13,700	112,150	10.94	.8	
9	4 P. M.	1,568	14,280	14,800	127,950	11.00	.85	
10	5 P. M.	1,624	15,904	14,400	142,350	11.00	.85	
11	6 P. M.	1,344	17,248	10,800	153,150	10.91	.67	
12	7 P. M.	1,512	18,760	10,800	163,950	10.73	.8	
13	8 P. M.	1,568	20,328	13,750	177,700	10.75	1.1	
14	9 P. M.	1,736	22,064	15,050	192,750	10.73	1.4	
15	10 P. M.	1,232	23,296	12,500	205,250	10.83	1.1	
16	11 P. M.	1,848	25,144	8,150	213,400	10.43	.3	Cleaned fire.
17	Midn't.	1,288	26,432	13,500	226,900	10.57	.55	
18	1 A. M.	1,680	28,112	16,500	243,400	10.65	.7	
19	2 A. M.	1,400	29,512	13,800	257,200	10.71	.6	
20	3 A. M.	1,512	31,024	13,500	270,700	10.72	.75	
21	4¼ A. M.	1,456	32,480	13,900	284,600	10.77	.9	
22	5 A. M.	1,456	33,936	12,150	296,750	10.75	1.0	
23	6 A. M.	1,848	35,784	14,700	311,450	10.70	1.25	
24	7 A. M.	1,960	37,744	14,200	325,650	10.57	1.2	

Average evaporation from and at 212 degrees Fahrenheit during 24 hours, 10.57 pounds of water evaporated per pound of coal.

NAVAL BOILERS.

The introduction and adoption of water-tube boilers in preference to cylindrical boilers in men-of-war is, perhaps, one of the most striking steps in the history of naval engineering. It marks an epoch in the annals of naval practice unlikely to be equalled in importance till steam engines and boilers alike are finally discarded for some more efficient means of providing power for the propulsion of our ships. The results in warships are greater speed, wider radius of action and increased armaments. The navy that refused to secure these advantages would, in case of war, be lost.

The rapidity and magnitude of the change can be gauged from the facts that ten years ago, except for a few French ships, practically no vessels were fitted with water-tube boilers, while to-day the total power of such boilers fitted or being fitted in warships reaches the immense aggregate of 6½ million horsepower. Taking only our own ships, the horsepower runs up to over 2 millions, while France, Russia, Germany, United States and Japan together have water-tube boilers fitted with a total horsepower of 2½ millions. Every country has adopted them, and though in the most important navies the Belleville has been more largely used than any other, yet it is worth noting that Germany has only tried it in the *Hansa* and *Hertha*, second-class cruisers, and America has held entirely aloof from it. There are, roughly, some twenty kinds of water-tube boilers in general use, and these are divided into two classes—large-tube boilers and small-tube boilers. The former have tubes from 2 inches to 4 inches in diameter and ¼ inch thick, and the latter have tubes about 1⅛ inches in diameter and ⅛ inch thick. It is regarded as a sound principle in our own Navy that the first are the only suitable boilers for battleships and cruisers. The small-tube boilers are mainly used in torpedo boats and destroyers. Large ships must be able to remain on distant stations for fairly long periods without requiring extensive repairs, and their boilers therefore must be durable. In the smaller craft everything has to be sacrificed to speed. The larger and thicker tubes stand a

much greater amount of wear than the thin tubes of smaller diameter.

The following are the principal boilers:

1. *Large-Tube Boilers.*—Belleville, Niclause, Dürr, Babcock & Wilcox, D'Allest and Yarrow.

2. *Small-Tube Boilers.*—Thornycroft, Yarrow, Schulz, Normand, Du Temple, Guyot, Reed, Blechynden, &c.

It will be noticed that there are two Yarrow boilers. They are of similar design, but fitted with different size tubes.

As the readers of "Engineering" are familiar with the general features of these boilers, it is not necessary here to point out the essential differences in their construction. As regards the ultimate outcome of the present struggle for the supremacy, it must be a case of the survival of the fittest. Now, no one boiler can claim advantages sufficient to justify its exclusive adoption. The final judgment can only come after years of experience, though the comparative trials now taking place in France, America and in our own Navy, will help forward the solution of the problem. The British Boiler Committee are only concerned with the large-tube types, and their work so far includes trials with the Belleville in the *Hyacinth*, trials with the Babcock & Wilcox in the *Sheldrake* and *Espiègle*, those with the Niclausse boilers in the *Seagull* and *Fantome*, and the more recent ones with the Yarrow and Dürr boilers in the third-class cruisers *Medea* and *Medusa*. (Referred to elsewhere under Ships:—England.—EDITOR.) The second-class cruiser *Hermes*, whose Belleville boilers were such a signal failure, has been fitted with Babcock & Wilcox boilers, the trials of which are looked forward to with great interest.

The following tables are designed to show to what extent water-tube boilers have been applied to naval vessels. They include all the navies of any importance and all ships built or building:

TABLES SHOWING APPROXIMATE HORSEPOWER AND TYPES OF WATER-TUBE BOILERS FITTED IN OR BEING SUPPLIED TO SHIPS OF THE PRINCIPAL NAVIES. TORPEDO BOATS AND DESTROYERS ARE NOT INCLUDED.

(NOTE:—Corrections have been made to include later information. *Tonnage should be less than shown by transfer to † in same section. ‡Tonnage greater than shown.—EDITOR.)

Type of boiler.	Number of ships.	Tons.	Horse-power.
Great Britain.			
Belleville, . .	59	621,100	937,900
Babcock & Wilcox, .	17	†145,000	244,000
Yarrow, . . .	13	58,400	101,800
Niclausse, . .	8	†42,800	113,000
Thornycroft, . .	10	18,200	59,600
Dürr, . . .	3	19,400	43,500
Laird-Normand, .	5	10,600	42,600
Reed, . . .	7	8,000	41,800
Type not known, .	16	*119,200	137,100
Total,	138	1,042,700	1,721,600
France.			
Belleville, . .	35	239,200	385,800
Niclausse, . .	20	†131,300	239,000
D'Allest, . . .	17	98,200	158,000
Guyot, . . .	3	29,600	71,000
Normand-Sigaudy, .	4	19,300	57,900
Various, . . .	8	19,000	30,300
Type not known, .	5	*90,700	134,300
Total,	92	627,300	1,076,300
Russia.			
Belleville, . .	31	245,200	336,600
Schulz, . . .	3	15,500	60,000
Normand, . .	3	20,000	58,000
Yarrow, . . .	2	6,200	34,000
Niclausse, . .	4	†20,700	42,000
Type not known, .	2	*15,700	30,000
Total,	45	323,300	560,600
Germany.			
Schulz, . . .	27	166,300	151,700
Dürr, . . .	10	79,500	119,200
Thornycroft, . .	8	35,400	33,400
Belleville, . .	2	11,500	20,000
Niclausse, . .	2	8,300	16,400
Type not known, .	9	77,600	103,000
Total,	58	378,600	443,700

Type of boiler.	Number of ships.	Tons.	Horse-power.
United States.			
Babcock & Wilcox, .	33	221,500	356,000
Niclausse, . .	6	75,000	108,000
Thornycroft, . .	3	27,800	34,400
Normand, . .	2	4,400	4,400
Yarrow, . . .	1	1,300	2,500
Type not known, .	3	40,500	43,000
Total,	48	370,500	547,500
Japan.			
Belleville, . .	11	109,900	155,000
Niclausse, . .	5	‡8,400	60,000
Normand, . .	1	800	5,500
Total,	17	119,100	220,500
Italy.			
Belleville, . .	6	71,800	121,000
Niclausse, . .	4	‡14,700	47,000
Babcock & Wilcox, .	1	12,600	19,000
Blechynden, . .	2	2,600	14,200
Total,	13	‡89,100	201,000
Austria.			
Yarrow, . . .	7	45,900	78,400
Belleville, . .	5	36,700	58,800
Various, . . .	2	1,500	6,800
Total,	14	84,100	144,000

TABLE SHOWING APPROXIMATE HORSEPOWER OF WATER-TUBE BOILERS FITTED OR BEING SUPPLIED TO TORPEDO-BOAT DESTROYERS.

Country.	Number of vessels.	Tons.	Horse-power.
Great Britain, . .	130	43,000	737,000
Russia, . . .	54	16,900	258,000
Germany, . . .	38	12,900	200,900
France, . . .	37	10,800	208,700
United States, . .	20	8,000	146,300
Japan, ...	20	6,400	121,600
Italy, ...	15	4,800	82,800
Spain, ...	4	1,500	28,500
Total,	318	104,300	1,783,800

20 —"Engineering."

TURBINE PROPULSION.

In reviewing engineering progress during the year 1903, the London "Engineer" mentioned recently as one of the most noteworthy departures of that period the extended use of the steam turbine for marine propulsion. The circumstances, it was remarked, closely resemble those under which the compound engine and surface condenser were introduced nearly forty years ago. Then, serious objections were raised to the innovation; grave doubts were entertained; anticipations of evil prevailed. But progress went on. In the same way the steam turbine has grown day by day in favor, and from finding with difficulty a place on torpedo destroyers, it is now in use in Channel steamers, and before the year has passed it may be found in Atlantic liners of the largest class, to say nothing of war ships. It is believed, however, that the marine steam turbine of the future will be very different in form from that fitted, say, to the Channel steamer, the *Queen*, recently shown in these pages. The Parsons type of engine, the "Engineer" goes on to say, occupies a great deal of floor space, and very little height. It takes up as much deck room, so to speak, as a piston engine of the same power. This in a man-of-war would be a decided advantage, but for a merchant ship it is not. In such a vessel it is better to save floor space than height—that is to say, to shorten the engine room, and for this reason it is desirable that a turbine in which the flow is radial instead of parallel should be adopted. There is, besides, the advantage that by using turbine wheels of larger diameter, the necessary high circumferential speed can be got, although the speed of rotation is moderate, and in this way we can dispense with toy propellers, which are not at all suitable for the rough-and-tumble life of ocean steamers, finding their way in and out of crowded docks and rivers. It is true that the parallel-flow type dispenses with a thrust block, the steam pressure on the vane wheels taking its place. But this, after all, is not a very serious consideration; and even if it were, it is by no means impossible to construct the engine in such a way that steam could still take the place of metal. The enormous quantity of condensing water required is always available at sea, and

there is nothing very wild in the prophecy that with the next decade the piston marine engine will have given way to the turbine. As it is, more than one great firm of marine engine builders are laying their plans for the manufacture of the turbine marine engine on a very large scale indeed.

Here it may be interesting to note that the efforts which the United States Navy Department has been making during the past year to have marine steam turbines tried on a large scale are promising early results. The special board, appointed by the Department a few months ago, to examine into the adaptability of steam turbines for war ships, has made a report to the effect that the demonstrated efficiency of this form of motor is such as to justify the provision of turbine installations for two scout ships of about 3,000 tons each, which it is proposed to ask Congress to authorize in the naval appropriation bill. The present plan of the Navy Department with reference to the use of turbines in the scout ships is to ask Congress to make immediately available the special appropriation of $25,000 requested by Admiral Rae, chief of the Bureau of Steam Engineering, for experiments with turbines, and also an allotment of the estimated cost of the two scout ships sufficient to cover their engines and boilers. Without special provision neither of these sums would be available until July 1 next, but the Department desires that the investigation now on foot shall proceed as rapidly as possible. The speed to be specified for the scout ships will probably be 23 knots, and this will require, roughly, 10,000 horsepower for each vessel. The installation of turbines in vessels of this size will be a most important step in naval construction, and its bearing upon the future of the merchant marine as well will be a matter of great interest.

EXTRACTS FROM THE ADDRESS OF SIR WILLIAM HENRY WHITE, PRESIDENT OF THE BRITISH INSTITUTION OF CIVIL ENGINEERS.

TURBINES.

"The steam turbo-motor, first applied to ship propulsion by Mr. Charles Parsons in the *Turbinia*, enables a further saving of

weight to be effected as compared with the quickest-running and lightest reciprocal engines. In the *Turbinia* extreme lightness was attained, the total weight of machinery, boiler, shafting and propellers being 22 tons for an estimated horsepower of over 2,000, nearly 100 H.P. per ton of weight. This is about twice the power in proportion to weight as compared with a destroyer. This vessel had a boiler of special type, which was forced considerably, and her runs at full power were of short duration; moreover, she had no reversing turbines for steaming astern. These features of the design sensibly reduced the weight. Other examples of the turbine system, however, furnish a fairer comparison with reciprocating engines, and make it certain that with a much slower rate of revolution than in the *Turbinia*, and with additional turbines for going astern at good speed, it is possible to effect considerable proportionate economies of weight or to increase speed. The destroyer *Viper*, with turbine machinery, was practically identical in dimensions with other destroyers having reciprocating engines, and she attained a maximum speed of about 36.6 knots on an hour's trial and about 34 knots for three hours with the contract load on board. The latter speed is about 3 knots greater than the corresponding speed on some of the best of similar destroyers with reciprocating engines and 4 knots above the guaranteed speed of the latter. Messrs. Denny estimate that if the Clyde passenger steamer *King Edward* had been fitted with balanced twin triple-expansion engines of the best type instead of turbines, in association with the same boilers, the speed would have been reduced from 20.5 to 19.7 knots, corresponding to a difference of 20 per cent. in horsepower. As one who, from the first introduction of the steam turbine by Mr. Parsons in 1884, has been intimately acquainted with his work and with the difficulties he has overcome in the application of turbo-motors to various purposes, I would testify to the great courage and ability he has displayed throughout. In regard to the special application of turbo-motors to ship propulsion the difficulties have been greatest, and have only been surmounted by scientific and experimental work of the highest order."

Oil Fuel for Marine Boilers.

"There is universal agreement that the advantages of oil fuel over coal are very great. It appears that experience during the last year practically confirms the conclusions reached by my friend, Colonel Soliani (late of the Italian Navy), who thoroughly investigated the question ten years ago. Oil fuel, to produce a certain evaporation, is from 30 per cent. to 35 per cent. less in weight than its equivalent in good steam coal when properly burnt. Special arrangements in the furnaces are required to secure efficient combustion, and to protect plate surfaces. With water-tube boilers, other modifications are necessary to secure that result, but it can be obtained according to recent experiments. It may be hoped that ere long the Admiralty will, as in many previous instances, place the results of their investigations before the engineering and shipping communities; more especially as other countries have had larger experience with oil fuel. There is no need to speak of the saving in labor in the shipment and transport of coal, stoking, and removal of ashes; or of the advantages in many other operations of the stokeholds. Taking an Atlantic liner of 40,000-H.P., carrying say 3,700 tons of coal, about 2,500 tons of oil should suffice, and 1,200 tons should be added to freight-earning capacity, besides the saving on cost of labor. But it is as true now as it was in 1893, that the question of adequate supplies of liquid fuel and continued reasonable price has to be settled before its extended use can be contemplated. That question remains without a satisfactory answer."

System of Twin Screws.

"A notable feature in modern steamship construction is the largely-extended use of twin screws. This system was proposed in the earliest days of steam navigation, and it was adopted practically half a century ago on a small scale. Between 1860 and 1865 a considerable number of twin-screw vessels were built, mostly vessels in which high speed was desired on moderate draught of water. Experience with the last rigged iron clads (*Alexandria* and *Temeraire*) enabled me in 1878 to make an extended analysis of their propulsive efficiency, and a comparison

with that of a number of single-screw ships of recent construction and deep draught. My conclusion was that, on the whole, the efficiency of the twin-screw ships was superior, which was contrary to the opinion generally entertained at that time. This opinion was not very favorably received at the time. Little was done towards adopting twin screws in mail steamers for eight or nine years. Then came the question of realizing 20 knots on the Atlantic service; and my friend, the late Mr. Thomas Imray, who had carefully studied my statements of 1878, consulted me when the design of the *Teutonic* and *Majestic* was being prepared by Messrs. Harland & Wolff. Enlarged experience had only confirmed my conviction and emphasized my recommendation of twin screws. They were adopted in the ships named, and in the two 20-knot ships built for the Inman Line about the same time—the *City of Paris* and *City of New York*. From that time it was certain that twin screws would take the place of single screws for swift mail steamers.

Triple and Multiple Screws.

"Triple and multiple shafts and screws have also been used for long periods in exceptional cases where shallowness of draught governed the dimensions of propellers. Cases in point are the floating batteries for river service, built during the civil war in America, with four shafts; the Russian circular ironclads, which had six shafts, and the Russian imperial yacht *Livadia*, which had three shafts. In recent years triple screws have been used in warships built in the United States, France, Germany and Russia, but not in ships of the Royal Navy, except turbine-propelled vessels of small size. In the United States after building, about ten years ago, two triple-screw ships of 19,000 H.P. to 20,000 H.P., which were reported to have done well, and, in face of the strong advocacy of the extension of the system by the engineer-in-chief (Admiral Melville), twin screws have been preferred for later battleships and cruisers up to 25,000 H.P. The Italians, after trials of triple screws in small vessels, have universally adopted twin screws. In France and Germany triple screws are generally adopted for battleships and cruisers, and in

Russia a number of triple-screw cruisers have been built, but the great majority of ships have twin screws. Having been personally responsible for the continued use of twin screws in British ships up to 1902, it may not be out of place to put on record the reasons for that action, more especially as there have been repeated misrepresentations of the facts by ill-informed persons, whose fundamental idea seems to be that foreign practice must necessarily be superior to British, and nothing but sheer obstinacy can account for a refusal to follow the lead of foreign designers. At first it was claimed that triple screws gave better propulsive efficiency than twin screws. Having had exceptional opportunities of making a thorough and extended analysis of the actual performances of many ships, I have to state that this is not the case. The advantage in this respect is distinctly with twin screws so far; and although it is possible that, with larger experience, the performance of triple screws may be improved, and approach, or equal, that of twin screws, it is practically certain that, under existing limitations of draught, and with reciprocating engines making the number of revolutions and piston speeds now accepted, there is no reason why triple screws should be preferable to twin screws up to 40,000 H.P. There are many instances of distinct inferiority in triple-screw ships, and my foreign friends, who are building these vessels, admit this, urging that there are compensating advantages.

"Of course, with three shafts and engines the manufacturing difficulties are less than with two shafts and engines. This was avowedly the reason why the two triple-screw American cruisers were built; but the great development of steel manufacture in the United States has removed that difficulty. Another gain by having three engines is said to be the possibility of running them faster and reducing the sizes of parts, thus saving weight and increasing economy of fuel when the vessels are cruising at low speeds. There may be some weight in this argument, but it is not of primary importance, and experience seems to show that with triple screws much greater power has to be developed at cruising speeds than is needed with twin screws. Still another argument, and one most relied upon apparently by advocates of

triple screws, is, that at these cruising speeds it is possible to throw one or more engines out of work, and so to avoid losses on engine friction, condensation, etc., thus economizing coal. Here there has been repeated change of ground, as trials have shown the fallacy of the contention. First, all three engines were made of equal size, and this is still the general practice. It was intended that at low speeds only the center engine should be at work, and that the two side screws should be disconnected and allowed to revolve. On trial, I am credibly informed, and can well believe, the drag of the wing screws added so seriously to the resistance that the power required for a given speed was from 40 to 50 per cent. greater than that required when the center screw was stopped and the side screw worked. Obviously, under these circumstances, the center screw also caused a drag, and more power was needed than in a purely twin-screw ship.

"The Russians in the *Rossia* followed this idea to its logical conclusion, and made the screws and engines large enough to utilize the full steam power at full speed, making the center engine only large enough to drive the ship at 10 knots, and fitting a feathering screw on the center shaft. On trial this intention was realized, and the ship attained 10 knots with the side screws disconnected and revolving, the center engine developing nearly 3,000 H.P. This compared most unfavorably with the performance of the cruisers *Powerful* and *Terrible*, in the design of which I adhered to twin screws. These ships are of 2,000 tons greater displacement than the *Rossia*, but, working both screws, they require only 2,000 H.P. for 10 knots, and are much more economical. Their engines, moreover, have a maximum power of 22,000 as against 16,500 H.P. in the *Rossia*, and they are about 2½ knots faster.

"In view of these facts another alternative has been proposed by Admiral Melville, namely, to make the center engine large enough to develop one-half of the total power, and the side engines each to develop one-fourth of the power. So far as I am informed, this plan has not been tried, and there seems no sufficient reason for making the experiment. His colleagues on the Board of Construction in the United States evidently were not

convinced, and the responsible designers of triple-screw ships in France and Germany have not adopted the suggestion. The conclusion reached by most naval architects confirms the opinion I have expressed, that, up to date, twin screws are to be preferred, and give better propulsive efficiency, while experience demonstrates that with proper forms of ships excellent maneuvering qualities can be secured. Against breakdown no doubt triple screws give one more chance of avoiding total disablement; but large experience shows that for all practical purposes twin screws give a sufficient margin of safety. Triple-screw engines also require greater space.

"In conclusion, may I quote a few words written ten years ago: 'It is reasonable to suppose that as higher speeds are attained and larger powers have to be utilized, since the limits of draught for ocean-going steamers are fixed by practical considerations, triple screws may become necessary to efficiency.' In my judgment that point has been reached, and the use of turbine engines with higher rates of revolution will also render desirable the adoption of three or four shafts, although the diameters of screws will be made relatively smaller. From first to last my desire has been to keep an absolutely open mind on this and all other questions affecting the efficiency of our war fleet. No pains have been spared to ascertain and analyze facts; every suggestion for possible improvement, from whatever source arising, has been welcomed and carefully considered, and every endeavor made to arrive at the right conclusion, but the responsibility for decision necessarily rests with the designer on questions of resistance and propulsion, and that responsibility I have never attempted to avoid.

QUESTION OF WATER-TUBE BOILERS.

"The last advance in marine engineering to which reference will be made is that connected with the use of water-tube boilers. Up to 1892 no attempt was made to fit water-tube boilers in any vessel of the Royal Navy above the size of torpedo boats and destroyers. My visit to France that year greatly impressed me, and the opportunities I then had of conferring with leading French naval architects and marine engineers convinced me that

the position demanded serious consideration. These gentlemen, whose professional ability and experience were unquestioned, while their desire to avoid undue risk was obvious, had arrived at the conclusion that experience with Belleville and other water-tube boilers justified the exclusive use of that type. The Belleville boiler had then been tried afloat to some extent for thirty-seven years and was chiefly used in the vessels building at that time; but the Niclausse and D'Allest boilers were also receiving trial. This was a great experiment no doubt, but made after full consideration. Its result, if successful, was to give the French fleet a definite superiority in speed over British ships, if we persisted in using cylindrical boilers.

Soon after (in 1893) I began work on the design of the cruisers *Powerful* and *Terrible*, vessels which were intended to surpass in speed and power all foreign cruisers then built or building. The superior results in speed obtainable with water-tube boilers necessarily received careful consideration; and various alternatives were compared before the boiler arrangements were decided. The engineer-in-chief (Sir John Durston) finally recommended Belleville boilers, with which much greater experience had been gained than with any other type of water-tube boiler. I concurred with his recommendation, and gladly accept my share of the responsibility. The Board of Admiralty approved, and the orders were placed. There is, I submit, no reason whatever for regret or apology in the light of subsequent events for the action then taken. On the contrary, in my judgment, it has had greatly beneficial results for the Royal Navy itself, and will have far-reaching effects upon steamship design generally. So much misunderstanding, to say the least, has arisen in regard to the circumstances under which the introduction of water-tube boilers took place, that it seemed desirable to place the facts on record. Ten years have elapsed since the change was begun; it has since been carried through not merely in the Royal Navy, but in all war fleets. The French have the honor of initiation; in this country we have not blindly followed their lead, but taken our own way. At present, no warship is building in which either water-tube boilers are not exclusively used, or associated with a

few cylindrical boilers developing about 20 per cent. of the maximum power.

"Into the controversies of the last four years I do not propose to enter. Hitherto, on account of ill health and for other reasons, I have refrained from any public utterance on the subject. All that is necessary now is to state my conviction that those who have taken the most prominent part in attacking the policy of the Admiralty have exhibited an imperfect knowledge of facts and principles; have failed to appreciate the weight of authority against their contention, represented by the universal agreement of naval authorities in all countries that water-tube boilers are essential to modern warships; and have shown, in many instances, a spirit of prejudice and personality that should never have been displayed in the discussion of a technical subject affecting the naval defence of the empire. My personal attitude in this matter was explained here more than four years ago, and has been consistently maintained throughout. Mistaken I may be, but I claim to have been consistent. Speaking in this institution in March, 1899 (at the close of a discussion on water-tube boilers), I said: 'Everyone agreed that the water-tube boiler—not meaning any particular boiler—was the safest boiler to use with high pressure. Everything in both the papers pointed to the circumstance that, as yet, the perfect water-tube boiler had not been found. I should like to know how it was ever likely to be found if experiments were not made.' My feeling is, and always has been, that it would be folly for us to remain inert while foreign navies were moving on lines promising great possibilities of advantage; and that, so long as we took only equal risks with them, experiments involved no loss of relative standing.

I have always maintained that experiments on various types, having features of the greatest promise, were not merely desirable, but absolutely necessary. Foreign critics make no assertion that we have prejudiced our relative position by the general adoption of the water-tube boilers. Everyone who studied the last naval maneuvers must have seen how superior was the steaming capability of the most modern battleships and cruisers compared with those of earlier date with cylindrical boilers. As all

the ships which were comparable were built from my designs the comparison is narrowed to that of the propelling apparatus, and the practical conclusion is irresistible. The position has been made clearer by the investigation and finding of the department committee on water-tube boilers appointed by the Admiralty three years ago. No one can dispute the ability—and I am convinced of the impartiality—of this body. It is an honor to this institution that so many of those who have rendered valuable service to the country under circumstances of great difficulty are our fellow members, eminent both for scientific and technical attainments. It would be too much to expect that their conclusions will command universal assent; but it is unquestionable that these conclusions rest on a great series of experimental trials and a close scrutiny of evidence. No attempt will be made to recapitulate these conclusions; they are to be found in many blue books, well deserving study by all interested in ship construction and propulsion."

Sir William White then sketched the proceedings of the committee and the trials of the *Minerva* and the *Hyacinth*. He then went on:

"There is other and quite recent evidence, however, of great interest, and I am enabled to give the figures by the courtesy of the Controller of the Navy. The cruisers *Spartiate* and *Europa*, fitted with Belleville boilers, have recently made voyages to China and back. On the voyage out the *Spartiate* averaged 12.65 knots, steaming easily and developing less than 20 per cent. of her full power. Her average coal consumption for all purposes was 2.29 pounds per indicated horsepower per hour. The *Europa* was sent out at a still lower power—about 13 per cent. of the maximum, the average speed being 10¾ knots. Her consumption was therefore higher, namely, 3.85 pounds per horsepower hour, and she burnt on the passage nearly 700 tons more than the *Spartiate*. This demonstrated the fact, previously well understood, that for covering distance the higher speed was more economical in a ship of the type with great engine power. But the most interesting fact remains to be stated: The *Spartiate* burnt nearly 1,200 tons less on the voyage than the *Blenheim*

did on the same voyage, the latter being 2,000 tons smaller in displacement, and having cylindrical boilers. The *Europa* burnt nearly 500 tons less. Allowing for differences of size and speed, the *Spartiate* is more economical than any modern cruiser with cylindrical boilers that has made the passage. The concluding run for both ships was made from Gibraltar to Plymouth on the homeward voyage. The *Europa* averaged 17.56 knots and consumed 2.06 pounds of coal per horsepower hour; the *Spartiate* averaged 18.11 knots with 1.7 pounds consumption. At the end of such a voyage these were very good performances, comparing favorably with the consumption of the most modern types of cruisers fitted with cylindrical boilers. No doubt greater economy is secured in mail and passenger steamers, but the only fair comparison is between warships with cylindrical and water-tube boilers, the mercantile conditions being so radically different, as already explained.

"The *Challenger*, fitted with Babcok & Wilcox boilers, on her recent contractor's trials had the moderate and uniform consumption of $1\frac{3}{4}$ pounds per horsepower hour at full power, 80 per cent. of full power, and 20 per cent. The *Hermes*, with the same type of boiler, consumed 1.54 pounds on a six-hours' trial. This is not, of course, long enough to determine consumption accurately. Both these ships were new, and, of course, in perfect condition.

"The first trials of the Yarrow large-tube boiler in the *Medea*, under the direction of the boiler committee, are incomplete, and the results as to coal consumption are therefore not available. It is understood, however, that in this respect there are good prospects of very satisfactory results.

"The Niclausse type of boiler for marine purposes is made in this country by Messrs. Humphreys & Tennant, who have received orders from the Admiralty for an aggregate of over 100,000 H.P. distributed over four cruisers and one battleship. One of the cruisers has passed through her trials with great success. Experience on service has yet to be gained.

"The most recent orders for boilers for British ships are reported to be divided principally between the Yarrow and Bab-

cock & Wilcox types, and it would appear, therefore, that these are for the moment looked upon as the most suitable types available, although the Niclausse has been adopted for several important ships. Valuable information will be obtained from the trials of all three types. The aggregate power in each type of boiler is very great, and the experiment is on an extremely large scale; but we cannot stand still, nor would any responsible and well-informed person now recommend cylindrical boilers for cruisers or battleships. Other navies are similarly circumstanced, and out of these trials here and abroad will come the data for deciding on the most efficient type of water-tube boiler.

MODEL EXPERIMENTS AND PROGRESSIVE STEAM TRIALS.

"Possibly the greatest advance made in scientific method is that connected with experimental determinations, initiated by William Froude, of the water resistance to the motions of ships. There had been numerous experiments on resistance previously, but no practical result of importance had followed. So late as 1868 a Committee of the British Association, including many eminent men of science, recorded the opinion that models could not be employed to determine the resistance of full-sized ships, and recommended towing experiments on the latter. Froude dissented, and proposed a system of tank-experiments based on a 'law of comparison' between ships and models which he had independently established on the basis of Rankine's stream-line theory of resistance. This law had been previously laid down by an eminent Frenchman, M. Reech, in his course of lectures at the School of Application of the *Genie Maritime*, but the fact was not known here. Moreover, Froude dealt with the question of frictional resistance in an entirely original manner, and on this depended the success of the system. Everyone knows that complete success was attained and demonstrated by the towing experiments authorized by the Admiralty on H. M. S. *Greyhound*. From that time onwards, a problem previously insoluble, has been rendered easy of solution. Estimates of power for speed have been made more certain, and the naval architect has been able to proceed with greater confidence in attempting unprecedented

speeds, and selecting the forms best adapted to the conditions of any design. After thirty years' experience in the Admiralty the system is in use not merely by some of the leading private shipbuilders in this country, but by the naval authorities in France, Italy, Germany, Russia, Holland and the United States. So far it has been applied almost entirely to experiments on ship models and model propellers; but it gives facilities for research on many obscure problems in hydro-dynamics, and it may be hoped that it will be so applied in connection with the National Physical Laboratory or the engineering departments of our Universities. At the technical High school at Charlottenburg an experimental tank has already been established.

"Progressive steam trials form a necessary complement to model experiments on resistance, since the relation of the effective horsepower of models to the indicated horsepower of ships varies in different cases, and unless that relation has been ascertained model experiments would not furnish a close approximation to the engine power required in a new design. Even apart from such steam trials, model experiments would be of great value of course, enabling the resistances of alternative forms to be compared, and so the best combination effected of form, stability, draught and economical propulsion in any case. The naval architect has not to seek for a theoretical form of least resistance, but to discover the form which fulfils all the conditions laid down for any design, and gives the minimum resistance compatible with those conditions. He has to keep in view for all ships not merely resistance in smooth water, but the maintenance of speed at sea and good behavior. Further, in warships considerations of maneuvering power, protection and armament may compel him to accept a greater resistance and larger engine power as a factor in minimizing size and cost. These are but illustrations of the general principle that alternatives must be compared before the best selection can be made, and here tank experiments are of unequalled value.

Much to Learn About Screw Propellers.

"After sixty years' experience with the screw propeller it must be frankly admitted that we have very much to learn. The theory

of its action has engaged the attention of many eminent mathematicians in this country and abroad. Very many experiments have been made on various ships fitted with propellers of different dimensions and patterns, and in some instances remarkable economies of power or gains in speed have been obtained. Model experiments on screws have been carried out on an extensive scale, and very interesting results obtained. Certain general principles have been established, and many problems, at first obscure, have been solved. When all care has been taken and the fullest use made of available data, success is not assured in the choice of propellers when precedent is largely departed from. On the other hand, in most, if not nearly all, cases success is eventually achieved as the result of experimental trials; although there is often a possibility that even better results might be attained if the trials were extended. As details of the trials of British ships are always published, and naturally awaken interest—especially when difficulties temporarily exist in obtaining estimated speeds—there is sometimes a tendency to suppose that in Admiralty practice troubles with screw propellers are unusually numerous. This is not true; but it is correct to say that in such cases the Admiralty has given to the engineering profession the fullest information of the trials and the results in order to assist future practice. The case of the *Iris* in 1878 is one notable example. She was a twin-screw cruiser of exceptional speed. Recently there have been other notable examples, in the *County* and *Drake* classes of armored cruisers, for which I guaranteed the high maximum speed of 23 knots, anticipating that it would be exceeded, and a few details may be of interest.

"The *Drake* class attained or exceeded this speed on trial. There was reason to believe, however, from the progressive trials, that an increase in blade area was desirable. The original screws were 19 feet in diameter, 24½ feet pitch, and each screw had 76 square feet of blade area. With 116 revolutions per minute and 30,600 H.P. a speed of 23.05 knots was reached. The new screws were of the same diameter, pitch 23 feet, and blade area 105 square feet. With 122.4 revolutions and 31,400 H.P. a speed of 24.11 knots was attained—a gain of fully 1 knot in speed. From the progressive trials it was found that with 116 revolutions and

26,000 H.P. the new screws gave a speed of 23 knots, or a saving of 4,600 H.P. as compared with the first screws. The trials of the *County* class were no less interesting. The earlier trials were made with screws 16 feet 3 inches in diameter, 20 feet pitch, and 54 square feet of blade area. With 147 revolutions and 22,500 H.P. the speed attained was 22.7 knots, or three-tenths less than the estimate. The progressive trials again showed excessive slip at the higher speeds, and insufficient blade area. New screws had been ordered before these trials were undertaken, as it was considered from other trials that the blade area would probably prove too small. Further trials were made with screws having 50 per cent. greater blade area, the diameter being unchanged and the pitch decreased by 6 inches only. With 140 revolutions and 22,300 H.P. the speed of 23.6 knots was attained. On the latter trials the speed of 21.64 knots was attained with 16,500 H.P. for thirty hours continuous steaming; previously, with the original screws, 20.5 knots was realized. It may be added that the original screws for all these cruisers were designed after full consideration of the results of model experiments with screws, and experience up to date with the propellers of swift cruisers. The altered conditions in the new designs, however, made this large increase in blade area necessary, although at the time when the dimensions were settled no one concerned anticipated such a necessity. Obviously, it is very difficult on model screws of small size to correctly represent the conditions of water resistance to rotation and effective thrust in full-sized propeller. Possibly the conditions of the 'wake' of the model ship may also differ in some respects. The subject is one calling for extended experiment and analysis."

ELECTRICAL PLANTS FOR SHIPYARDS.

The speaker, Mr. W. M. McFarland, formerly in the Naval Service and now Vice President of the Westinghouse Electric and Manufacturing Company, said before the American Society of Naval Architects and Marine Engineers:

"Ten years ago a distinguished member of this Society read a paper at the Engineering Congress in Chicago entitled 'The Planning and Equipment of Modern Ship and Engine Building

Plants,' in which he discussed very thoroughly the subject of motive power and the methods of power transmission. The paper was an exhaustive one, and gave a very complete and satisfactory comparison of the various methods of the application of power in large manufacturing areas, such as a shipyard or engine-building plant. At that time, although electricity had been used for power transmission to an extent sufficiently great to justify our colleague in devoting several pages of his paper to a discussion of its advantages and disadvantages, he did not reach the conclusion that, all things considered, the electric drive was the best. He said: 'While there is certainly some combination which would result in the best all-round efficiency as a ship-producing plant, yet it is equally true that we have not sufficient data on which to form exact ideas of what such combination for any given case should be.'

"At the present time there can be little doubt that the question as to the best system of power transmission has been definitely settled in favor of electricity, and the quotation from this admirable paper has been given to show how rapid the strides of progress have been. Indeed, when the latest of our large shipbuilding plants was equipped, some six years after the date of the paper above referred to, the decision was in favor of the electric drive. So great are the advantages of electricity that not only is it used in preference to older methods in the case of new plants, where a decision as to the best method has to be made, but progressive managers are taking out older methods of power transmission and superseding them by electricity. In the past few years such well-known and long-established British firms as Harland & Wolff and Palmer's Shipbuilding and Iron Company have equipped their works electrically throughout.

"At the risk of taking up your time unnecessarily with an aspect of the case with which you are all familiar, we may consider very briefly the older methods of power transmission and their disadvantages, and contrast these with the advantages offered by the electric drive. Speaking broadly, the system of power transmission in almost universal use until five or six years ago was with the steam engine as a prime mover, driving a series of main shafts which, in turn, by means of countershafts

and belts, drove the individual tools. This, of course, was the case for a single shop of reasonable dimensions. In the case of an establishment covering a wide area, such as a shipyard or a very large manufacturing plant, the system has either a central boiler plant transmitting steam to engines located in different parts of the manufacturing area, or sometimes, in very large works, a number of boiler plants with some engines near them and others at a considerable distance.

"Compressed air was used to an extent greater, perhaps, than ordinarily supposed, although it was never in common use for transmitting power. It is interesting to note that there were extensive installations at the Cockerill Works, Seraing, Belgium, and at the Terni Steel Works in Italy. In a number of our New England cotton mills, where there was a surplus of water power, compressed air was used for transmission to places which could not conveniently be reached by belt or rope drive. The Dominion Cotton Mills, Canada, were originally driven entirely by compressed air. It is generally known that the Popp system of compressed air transmission was used in Paris on quite a large scale, several air-motor stations of considerable size being installed in connection with electric lighting. Nevertheless, the use of compressed-air was by no means general in industrial establishments for power purposes. At the present time compressed air is largely used in modern manufacturing for the operation of pneumatic drills, hammers, chisels, caulking tools and the like, but not for driving large power tools. Hydraulic transmission is used to a limited extent for certain special tools, such as large riveters and flanging machines, but from its nature it is not well suited for tools having a rapid motion, either rectilinear or circular, and although there have been a few large installations they have been very rare.

"The disadvantage of long lines of shafting was thoroughly realized before electricity offered such a simple solution of the difficulty. Unless the greatest care was used in keeping the shafting in alignment and the journals well oiled, the power wasted in the friction of bearings and belts was a very large percentage of the total power of the engine. The results of numerous experiments to determine these losses have been pub-

lished repeatedly, and show that they have varied from 8 or 9 to 80 per cent. of the power of the engine. That there should have been even the minimum loss when all the tools were in operation was bad enough, but unfortunately, from the nature of things, this loss was going on all the time, even when only a few tools were in operation, as it was practically constant and independent of the load. A preliminary solution of this difficulty was to divide the shafting into short lengths, driving groups of tools and operating each group by a small steam engine, but this introduced the lower efficiency of small engines and the complication of long lines of steam piping with the inevitable losses due to condensation. There was also involved additional supervision, as each engine would generally require a considerable part of the time of a man to look after it. With the case of a very large establishment with numerous power plants scattered over its area, the conditions were still worse for economy, as it was practically impossible to have the best skill at each one of these little plants, and, as a rule, they themselves were not economical.

"When we compare the conditions obtaining with electric transmission the contrast is very great. Instead of the long lines of steam piping, with their attendant condensation and heating of the spaces through which they pass, we have the small flexible wires conveying current, which can go anywhere, and as a rule are located in spaces not useful for other purposes. Both generators and motors have a high efficiency, and, speaking generally, the part of the apparatus requiring skilled attention is almost entirely concentrated in the power plant. There are no losses from condensation, and the analogous loss—that due to the heating of the wires consequent upon transmitting the current—is, for the distances common in industrial establishments, so small as to be a matter of little moment. The electric motors lend themselves readily to small subdivisions of power, the efficiency of small motors being only a little less than that of large ones, as contrasted with the enormous reduction in economy of small steam engines. In consequence it is practicable to use the motors either for individual tools or for groups of tools.

"There are a number of other interesting points in connection

with the use of electricity which might be mentioned, but they appeal rather to the electrical engineer than to the average member of our society, such as the most suitable number of alternations to be used if alternating current is adopted. In this matter a good deal depends on the extent of the plant and whether the lighting circuits are to be the same as the power circuits or not. For many reasons 3,000 alternations is the most suitable one for driving motors, but this is too low to give satisfactory service with arc lights, and also rather low for incandescent lamps. In such a case it may be desirable either to use an independent generator at 7,200 alternations, or perhaps a motor generator set, or even to make the exciters for the main generators large enough to use direct current for lighting. Again, it may be decided to use alternating current for power tools and direct current for cranes, in which case direct current may be obtained either from a rotary converter or from a 'double-ended' generator. This last was the method used at the New York Shipbuilding Co.'s plant and furnished an excellent solution. The beauty of this apparatus is that the current divides automatically to answer the demands upon it so long as the combined amount of alternating current and direct current does not exceed the capacity of the machine.

"Another useful application of electricity, if the plant is large enough, is the electric locomotive, which can be operated by either the overhead trolley, or the storage battery, or what is known as the 'button system.' This last does away entirely with live wires which can cause any injury, the so-called 'buttons' only being alive when the locomotive is over them.

"To sum up, we may say that by the use of electricity for power transmission we secure an enormous increase in the flexibility of design of the plant, being able to locate the power plant itself and the various shops where the circumstances of the case require them for efficiency, the lines for transmission being so small as to make moderate variation of length unimportant. We also secure a marked economy in the cost of power, a greater efficiency in the machine tools themselves, and a greatly increased efficiency of the personnel, due to the increased habitability and cheerfulness of the shops."

FLEETS OF RUSSIA AND JAPAN.

The following tables, showing the present strength of the fleets of Japan and Russia, are prepared for covenience of reference.

Ships marked with * in Japanese fleet have been completed and put in service since the Chino-Japanese war:

THE JAPANESE FLEET.

Name.	Date of launch.	Displacement, tons.	Armament.	Speed, knots.	Maximum coal capacity, tons.
Battleships, first class (six ships).					
**Mikasa*	1900	15,200	4 12-inch. 14 6-inch Q. F. 40 smaller guns.	18.6	1,690
**Hatsuse*	1899	15,000		19	1,690
**Asahi*	1899	15,200		18	1,360
**Shikishima*	1898	14,850		18.6	1,360
**Fuji*	1896	12,450	4 12-inch. 10 6-inch Q. F. 24 smaller guns.	19	1,300
**Yashima*	1896	12,300			
Battleships, second class (one ship).					
Chin Yen (China)	1881	7,220	4 12-inch (Krupp), 4 6-inch Q. F. 10 smaller.	13	1,000
Coast Defense Vessels (five ships). (Cannot fight at a distance from a base.)					
Hei-yen (China)	1888	2,067	1 10.2-inch. 2 6-inch. 8 smaller guns.	11	350
Fusoo (first armored ship for Japan)	1877	3,717	4 9.4-inch, 4 6-inch Q. F. 15 smaller.	11	360
Kongo	1877	2,248	2 6.7-inch, 6 6-inch (Krupp), 8 smaller.	12.5	.....
Hi-yei	1887	2,248			
Chiyoda	1890	2,450	10 4.7-inch Q. F. 17 smaller.	17.5	420
Cruisers, armored (eight ships).					
**Kasuga*	1902	7,700	4 8-inch (*a*). 14 6-inch. 16 smaller.	20	11,500 (10,000 miles at 10 knots.)
**Nisshin*	1903	7,700		20	
**Iwate*	1900	9,750	4 8-inch Q. F. 14 6-inch Q. F. (12 only in *Yakumo* and *Adzuma*). 20 smaller (19 only in *Asama* and *Tokiwa*).	21.8	1,200 to 1,600, equal to 7,000 to 10,000 mls. at economical speed.
**Idzumo*	1899	9,750		21	
**Yakumo*	1899	9,850		20	
**Adzuma*	1899	9,400		20	
**Asama*	1898	9,700		23	
**Tokiwa*	1898	9,700		23	
Cruisers, protected, first class (none).					
Cruisers, protected, second class (twelve ships).					
**Chitose*	1898	4,898	2 8-inch Q. F. 10 4.7-inch Q. F. 18 smaller	22.5	1,000 equal to ab't 4,000 mls. at 10 knots.
**Kasagi*	1898	4,784		22.5	
**Takasago*	1898	4,180		23	
Akitsushima	1892	3,100	4 6-inch Q. F. 6 4.7-inch Q. F. 12 smaller.	19	500
Yoshino	1892	4,180	4 6-inch Q. F. 8 4.7-inch Q. F. 22 smaller.	23	1,000
Hashidate	1891	4,210	1 12.5-inch (Canet). 11 4.7-inch Q. F. 19 smaller.	17 17.5 17	405
†*Matsushima*	1890				
Itsukushima	1889				

(*a*) One vessel is to have one 10-inch forward en barbette, in place of two of the 8-inch.
† *Matsushima* has 12 4.7-inch and only 16 smaller guns.

Name.	Date of launch.	Displacement, tons.	Armament.	Speed, knots.	Maximum coal capacity, tons.
Cruisers protected, second class (continued).					
Naniwa	1889	3,727	2 10.2-inch. 6 6-inch Q. F. 16 smaller.	18.7	800 equal to 9,000 miles at 13 knots.
Takachiho	1885	3,727	2 10.2-inch. 6 6-inch Q. F. 16 smaller.	18.7	.....
**Tsushima*	1903	3,365	6 6-inch Q. F. 14 smaller.	20	600
**Niitaka*	1902	3,365		20	
Cruisers, protected, third class (five ships).					
**Akashi*	1897	2,657	2 6-inch Q. F. 6 4.7-inch Q. F. 16 smaller.	20	600 equal to over 10,000 mls. at 10 kts.
**Suma*	1895			20	
Idzumi	1883	2,920	2 6-inch. 6 4.7-inch Q. F. 14 smaller.	17.4	600
Sai-Yen (China)	1883	2,264	2 8.2-inch. 1 6-inch. 14 smaller.	14.5	230
Otawa	1904	3,000	2 5.9-inch R. F. 6 4.7-inch R. F. 6 smaller.	21	.....
Cruisers, unprotected (six ships).					
Takao	1888	1,750	4 6-inch. 1 4.7-inch. 9 smaller.	15	300
Katsuragi	1885	1,478	2 6.7-inch. 5 4.7-inch. 7 smaller.	13	.....
Yamato	1880				
Tenriu	1883	1,540	1 6.7-inch. 6 4.7-inch. 6 smaller.	12	256
Kaimon	1882	1,345	1 6.7-inch. 6 4.7-inch. 6 smaller.	10.5	180
Tsukushi	1882	1,370	2 10-inch. 4 4.7-inch. 7 smaller.	16.5	300
Torpedo vessels (four).					
Miyako	1897	1,800	2 4.7-inch Q. F. 10 smaller.	20	350
Yaeyama	1889	1,583	3 4.7-inch Q. F. 8 smaller.	20	.....
Tatsuta	1894	850	2 4.7-inch Q. F. 4 smaller.	21	188
Chihaya	1901	850		21	200

Torpedo boat destroyers (nineteen).

Seventeen built and two building. Speed, 30 to 32 knots.

Torpedo boats (eighty-five).

7 divisional, 11 others building; 80 to 203 tons displacement.
33 first class, 7 others building
27 second class, 52 tons displacement.

Submarines (none).

RUSSIAN FLEET.

Ships marked
P are in the Far East—Pacific Fleet.
B are in the Black Sea Fleet.
J are to join the Pacific Fleet.
H are in the Baltic Fleet.
D reported damaged or destroyed by the Japanese.
† are fitted for liquid fuel.
‡ are gunboats.

Battleships (8 in Black Sea and 12 others.)

Name.	Date of launch.	Displacement.	Armament.	Speed.	Full coal capacity.	Radius of action at 10 knots.
		tons		*knots*	*tons*	*miles*
†*Rostislav*, B	1896	8,880	4 10-inch 8 6-inch Q. F. 28 smaller guns 4 torpedo tubes	16	800	2,000
Sebastopol, P, D *Poltava*, P, D *Petropavlovsk*, P	1894–5	10,960	4 12-inch 12 6-inch Q. F. 34 smaller guns 4 torpedo tubes	17½	1,050	3,400
Sissoi Veliki, H (*Sissoi the Great*) (Reconstructed 1902)	1894	8,880	4 12 inch 6 6-inch Q. F. 30 smaller guns 6 torpedo tubes	16	1,200	2,000
Tri Sviatitelia, B (*Three Saints*)	1893	12,400	4 12-inch 8 6-inch Q. F. 4 4-inch Q. F. 52 smaller guns 6 torpedo tubes	17¾	1,000	3,900
Georgei Pobiedonosets, B (*George the Victorious*)	1892	11,940	6 12-inch 7 6-inch 20 smaller guns 7 torpedo tubes	16½	1,000	4,000
Navarin, H	1891	9,476	4 12-inch 8 6-inch 32 smaller guns 6 torpedo tubes	16	1,200	...
Dvienadsat Apostolof, B (*Twelve Apostles*)	1890	8,400	4 12-inch 4 6-inch 32 smaller guns 6 torpedo tubes	16½	800	...
Sinop, B		10,181	6 12-inch	16½		1,350
Catherine II, B	1886–7	10,048	7 6-inch	15½	870	(at 14
Tchesme, B		10,930	14 smaller guns 7 torpedo tubes	15		knots)
Imperator Nikolai I, H	1889	9,200	2 12-inch 4 9-inch			1,500
Imperator Alexander II, H	1887	9,900	8 6-inch 22 smaller guns 6 torpedo tubes	16	1,200	(at 14 knots)
†*Peresviet*, P			4 10-inch	18		
†*Pobieda* (*Victory*), P	1898	12,674	11 6-inch Q. F. 50 to 54 smaller guns 5 torpedo tubes	to 19	2,056	...
†*Osliabya*, J			4 12-inch 12 6-inch Q. F.			
†*Retvisan*, P, D	1900	12,902	54 to 58 smaller guns 4 torpedo tubes in *Retvisan*, 6 in *Czarevitch*	19 19	2,000 1,350	8,300 5,500
Czarevitch, P, D	1901	13,100	4 12-inch 16 6-inch Q. F.			
†*Kniaz Potemkin Tavritchesky*, B	1900	12,480	28 smaller guns 5 torpedo tubes	17	900	3,000

Armored Cruisers (8)

Bayan, P	1900	7,726	2 8-inch 8 6-inch Q. F. 32 smaller guns 2 torpedo tubes	22	1,100	3,000 (at 18 knots)
Gromoboi, P	1899	12,364	4 8-inch 16 6-inch Q. F. 60 smaller guns 5 torpedo tubes	20	2,100	17,500

Name.	Date of launch.	Displacement.	Armament.	Speed.	Full coal capacity.	Radius of action at 10 knots.
Armored cruisers (continued).						
		tons		*knots*	*tons*	*miles*
†*Rossia*, P	1896	12,200	4 8-inch 16 6-inch 50 smaller guns 5 torpedo tubes	19½	2,500	19,000
Rurik, P	1892	10,933	4 8-inch 16 6-inch Q. F. 6 4.7-inch Q. F. 14 smaller guns 4 torpedo tubes	18¾	2,000	19,000
Pamyat Azova, H (Reconstructed 1902.)	1888	6,734	2 8-inch 17 6-inch Q. F. 17 smaller guns 3 torpedo tubes	18	1,000	10,000
Admiral Nakhimoff, H (Reconstructed 1900.)	1885	8,524	8 8-inch 10 6-inch No smaller guns 3 torpedo tubes	19	1,300	8,000
Dmitri Donskoi, J	1883	6,200	6 6-inch Q. F. 10 4.7-inch Q. F. 30 smaller guns 5 torpedo tubes	15½	400	4,800
Vladimir Monomoch, H (Reconstructed 1897–8.)	1882	5,593	5 6-inch Q. F. 6 4.7-inch Q. F. 26 smaller guns 3 torpedo tubes	15	400	.....
Protected cruisers (12).						
Bogatyr, P	1901	6,645	12 6-inch Q. F. 26 smaller guns 6 torpedo tubes	24	1,430	.....
Askold, P, D	1900	5,905	12 6-inch 24 smaller guns 6 torpedo tubes	24½	1,100	.....
Variag, P, D	1899	6,500	12 6-inch 26 smaller guns 6 torpedo tubes	23½	1,250	.....
Aurora, J	1900	6,731	8 6-inch			
Diana, P, D	1889	7,081	34 smaller guns	20	1,430	5,500
Pallada, P, D	1899	6,630	3 torpedo tubes			
Svietlana, H	1896	3,862	6 6-inch Q. F. 12 smaller guns 2 torpedo tubes	20¼	400	7,000
†*Novik*, P, D	1900	3,000	6 4.7-inch 9 smaller guns 6 torpedo tubes	26	600	5,000
Admiral Korniloff, H	1887	5,800	14 6-inch 18 smaller guns 6 torpedo tubes	18	1,100	15,000
Boyarin, P	1901	3,200	6 4.7-inch Q. F. 12 smaller guns 5 torpedo tubes	23½	650	5,000
Almaz, J (Ordered back later.)	1900	3,285	6 4.7-inch 11 smaller guns 6 torpedo tubes	25	500	6,000
Rynda, H	1885	3,508	10 6-inch 13 smaller guns 1 torpedo tube	15	700	2,400
Armored coast defense vessels (7).						
Gen. Admiral Apraxin, H	1896	4,126	3 10-inch 4 6-inch Q. F. 24 smaller guns 4 torpedo tubes	16	400	2,500
Khrabri, H	1895	1,735	2 8-inch 1 6-inch Q. F. 13 smaller guns 1 torpedo tube	15	200	.....

Name.	Date of launch.	Displacement.	Armament.	Speed.	Full coal capacity.	Radius of action at 10 knots.
Armored coast defense vessels (continued).						
		tons		*knots*	*tons*	*miles*
Admiral Seniavin, H	1894	4,126	4 9-inch 4 6-inch Q. F. 26 smaller guns 4 torpedo tubes	16	400	2,500
Admiral Oshakoff, H	1893					
‡*Otvajni* ‡*Gremiastchi* ‡*Grosiastchi* } H	1892 1892 1890	1,750 to 1,492	1 9-inch 1 6-inch 8 to 15 smaller guns 2 torpedo tubes	15	200	...
Old vessels built	1865–8	...	Little or no fighting value	...	...	...
Torpedo Vessels (9) 3 in Pacific Fleet.						
...	1889–96	400–742	6 to 15 small Q. F. guns	...	...	...
Torpedo-boat Destroyers (54) 30 in the Pacific Fleet. Built and building.						
...	1895 to 1902	240–350	1 12-pdr. Q. F. 3 small Q. F. guns 3 torpedo tubes	27–30	...	...
Torpedo Boats (169) 20 in the Pacific Fleet.						
First-class	1889 to 1900	80–215	Various	...	...	...
Second-class	...	...	...	...	...	...
Submarine Boats (2) Building.						
...	1901	...	...	...	...	...
VESSELS UNDER CONSTRUCTION.						
Battleships (12).						
Borodino	1901	13,516	4 12-inch 12 6-inch Q. F. 48 smaller guns 6 torpedo tubes	18	2,500	8,500
Imp. Alexander III.	1901					
Orel	1902					
Kniaz Suvaroff	1902					
Slava	1903					
Johann Slatust, B	...	13,000	4 12-inch 16 6-inch guns 20 smaller guns	18	...	...
Ersiaft, B						
Andrei Pervozvanni	...	16,500	4 12-inch 12 8-inch smaller guns 4 torpedo tubes	18	3,000	...
Imperator Paul I.						
Three unnamed, projected						
Armored Cruisers (2).						
Unnamed, projected	...	7,000	Will probably resemble the *Bayan*.	18	...	...
Protected Cruisers (5).						
Zemtchug	...	3,000	6 4.7-inch Q. F. 10 smaller guns 5 torpedo tubes	25	650	5,000
Izumrud						
Kagul, B	...	6,645	12 6-inch 26 smaller guns 6 torpedo tubes	23	1,430	...
Otchakoff, B						
Oleg						

PRODUCTION OF HIGH TEMPERATURES BY BURNING ALUMINUM, AND THE APPLICATION OF THIS TO ENGINEERING AND METALLURGY.*

By Dr. Hans Goldschmidt, of Essen-Ruhr, Germany.

The two elements of most frequent occurrence on our planet are oxygen and aluminum. By producing in a suitable manner the chemical combination of these two, a temperature is created which is about equal to that of the electric arc light. On this discovery is based the new science called alumino-thermics. The proper manner of combining aluminum with oxygen is not by taking the atmospheric oxygen, but the solid oxygen contained in the oxides; these are mixed with finely granulated or pulverized aluminum. The resulting mixture is the heat producer, and is called thermit.

The next aim is to produce this great heat in the simplest and most efficacious manner and then to discover the fields on which it can be applied to most advantage.

The first important discovery in observing the properties of this mixture—thermit—was that, when ignited in one spot, the combustion continued throughout the whole mass without any supply of heat from outside. The mass is placed in crucibles which are not in contact with any external source of heat, and the combustion, once started, embraces the whole mass in a very short time. This is the essence of alumino-thermics.

In the crucible after the reaction there are two layers. The bottom one is pure metal of equal weight to, but occupying only one-third of the space of, the top layer, which is now oxide of aluminum, so-called corundum.

These two layers, whilst still liquid, are poured rapidly over the rim of the crucible. It is not difficult to distinguish between the slag which flows first and the brightly glittering overheated metal.

(To demonstrate the heat created by this chemical reaction, the speaker used thermit to burn a hole through a 1-inch wrought-iron plate.)

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* Extract from lecture delivered at the annual meeting of the American Society of Mechanical Engineers at the Stevens Institute, Hoboken, N. J., December 3, 1903, by the inventor. ("Marine Engineering.")

You will notice that in this case the crucible is tapped from the bottom so as to allow the pure iron, which has a temperature of about 5,400 degrees Fahrenheit, to run out first. The hole is perfectly smooth-edged; the heat is so concentrated that the plate is still cold after the reaction.

Nearly fifty years ago attempts were made to apply the reducing properties of aluminum. Without exception, the experimenters heated their compounds externally. The reaction was always so violent that they could only operate with very small quantities. It will easily be seen that to arrive at alumino-thermics on a commercial scale from such a starting point required patient study and assiduous work. Each of the mixtures, although made according to simple chemical rules, required studying out by itself. The formulas for gun-powder or dynamite sound fairly simple, but it requires more than a mere mixture of the ingredients to obtain any effect sufficient for industrial requirements; not as if thermit were an explosive—you can throw it into the kitchen fire and it won't burn.

In all exothermic processes the physical properties of the ingredients, in this case particularly those of the oxides, want considering. Then the methods of manufacture have to be worked out for each case.

In the following I am going to illustrate by practical demonstration a few of the applications of the thermit process; to give an account of the entire field of its utility would go beyond the scope of a single lecture.

The applications may be roughly divided into two main divisions, the one concerning the metallurgist, the other the engineer. The latter application may be summarized in the word "welding." The study of the metallurgical application preceded that of the other.

Amongst the pure metals produced by the alumino-genetic reaction I may mention in the first instance chromium free of carbon as having already found a market in this country. It is used in the manufacture of particular qualities of chromium steel with a limited percentage of carbon. For instance, it is considerably used for self-hardening tool steel with 5 to 6 per cent. chro-

mium, about twice that quantity of tungsten and only .6–.7 carbon. . . .

This first division appertaining to metallurgy I shall abandon for the present in order to acquaint you with the process which has received the widest attention and practical application—the thermit-welding process.

Considering the innumerable details connected with the application of so new and practically unknown a force, it is not surprising that only since about a year ago the process has been introduced on a large and commercial scale.

The most important of these welding processes is the one by which a continuous rail—a necessity of modern trolley-road construction—is simply, cheaply, and effectively obtained. Engineers in this country, in which no less than 25,000 miles of single track are in existence, are watching the good results obtained in Europe with this system. European authorities recognize its advantages over all its competitors, about 20,000 joints having been welded by this process since about a year ago in forty cities of the old world. . . .

A marked advantage enjoyed by this system is the absence of any bulky equipment; all that is required is a crucible, a mold box, and, in some instances where a complete butt weld of the head of the rail is desired, a rail clamp. All these materials, including the necessary quantity of thermit, can easily be moved on a hand truck. Each weld, according to section, requires from fifteen to twenty pounds of thermit.

Even where a rail clamp is used the time employed is less than that necessary for fixing fish-plates and copper bonds. The mold is made according to a model designed specially for each section. Its two parts, one on each side, firmly enclose and exactly fit the rail. They are made on a large scale by manufacturers of refractory earthware, or, according to the requirements of the trolley-lines, in the repair shops, by tamping an ordinary mixture of China clay and loam into a sheet-iron case placed over the model, which has afterward to be dried during a couple of hours at a temperature of some 212 degrees Fahrenheit. The cost is only a few cents.

The thermit iron running out of the crucible flows around the web and foot of the rail, and, melting them, forms one mass with them. The liquid slag which follows the metal is diverted to the top of the rail, and brings the latter to welding heat. The whole section is thus heated equally, and the rail ends will not buckle. . . .

(Two rails were here welded by thermit.)

Working without clamps, the time consumed per joint equals three-quarters of an hour for one man; trained squads of four men, including foreman, did not use nearly so much time. At $1.50 per day, the wages item of cost is ten cents per joint. The use of the clamps doubles this amount. All other labor remains the same whether clamps are used or not.

The mold, which must be dry and porous, is screwed on to the rail, and the rims touching the rail are carefully smeared with clay. Before doing so, however, the rail ends are cleaned of dirt and rust with a wire brush and slightly warmed; a sand blast is superfluous.

In case the tops of the rails are to be butt-welded, the section has to be filed. This is all that is required in the way of preparatory work. A true alignment of the rail is an indispensable precaution. The rails require no bolt holes, as no provisional fish-plates are necessary.

You will recognize that none of this work demands special training, and that in this country, as in Europe, the trolley companies' men will be easily able to do it. A certain supervision to see that it is done carefully is a matter of course. The welding is done automatically and does not require the trained eye of an expert welder. In case of wet weather, the protection of a few planks is desirable to prevent the mold and thermit getting wet.

The next and only remaining appliance necessary for thermit welding is the crucible. This consists of a sheet-iron mantle lined with magnesia. It is of simple construction, the lining being introduced by tamping it round a cone, which is suspended in the middle of the mouth. The bottom is formed by a hard magnesia stone provided with an exchangeable outlet, which will

stand nine to ten runs. The crucible, with the cone in it, is placed in the furnace for only two hours and finally brought to glow heat. It is then ready for use. Crucibles will stand about twenty-five reactions, and the wear and tear will, therefore, amount to only a few cents per joint. The thermit is supplied in small bags containing the exact weight which is needed to effect the weld. These are called welding portions, and are sold as such to the trolley companies. The companies who make their own crucibles and molds will, therefore, have to pay freight only on the welding portions, which is considerably less than that on fishplates and bolts. The Essen works have a plant to supply over 500 welding portions daily.

The strength of the weld is about 80 per cent. of the strength of the original material. The shoe welded on to the foot of the rail not only makes up for the remaining 20 per cent., but materially strengthens the rail at the joint. The head does not get softer, although it is brought to welding heat; the reason being that the operation takes place without the air having access to it. Test rods cut out of rails brought to welding heat with thermit prove that tensile strength and elasticity have not suffered; a fact which is confirmed by three years' practical experience on the road.

Steel girders for construction work can, of course, be welded in just the same way as rails. For really solid jointing equal to the strength of the girder itself welding is cheaper than riveting. There will be a wide field for this work in the United States as soon as the preparatory experiments and calculations have been made and officially sanctioned. After the experiments you have seen here you will acknowledge the immense saving of time in using the welding process as compared to riveting.

The next field of application I shall now touch upon is an exceedingly wide one—the repair of solid iron and steel objects. Thermit, as I told you, gives 50 per cent. of mild, very overheated steel with .1 carbon, which can be hardened if desired, for instance by an addition of manganese. *Whoever has a supply of thermit has a supply of liquid steel.* Accordingly foundries can correct faulty castings, machinery shops can mend broken or

worn-out parts, and last, but not least, marine engineering works can repair large steel castings, such as crank shafts, and particularly broken stern posts.

Wherever the distance from construction shops is a matter of consideration, and in all outlying districts, this thermit is of particular value. Within the last few months regular ton orders have been received from South Africa, where damaged machinery of all kinds has been repaired by it in the mining districts. In many cases cast iron has been welded.

Certain rules have to be observed in all repair work. First and foremost, the slag should not be allowed to get mixed up in the plastic iron. An appropriate position of the runner and a little experience in the construction of the most effective shape of mold will prevent this. The mold must be made so as to allow the liquid iron which runs out of the crucible to flow freely round the flaw or fracture and to rise in the rising pipe. The latter must be large enough to hold sufficient metal, that the walls of the flaw, etc., are fused. The weld can be either effected by running the thermit iron round the ends of the piece in the shape of a ring, or by both running it between and around at the same time. The size of molds and quantity of thermit necessary for welding shafts up to 300 mm. diameter have been tabulated. A 12-inch diameter takes 190 pounds of thermit, giving 95 pounds of mild steel.

The most startling and at the same time most effective work done in the way of repairs by thermit is in connection with marine engineering. To weld broken stern posts of big transatlantic liners, or crank shafts or similar pieces, crucibles six feet in height with a capacity of seven hundred weight, have been constructed. The reaction in these takes hardly longer than in a small crucible. The enormous advantage offered to steamship owners by such repairs will be apparent when it is remembered that a broken stern post would otherwise have to be replaced by a new one. Besides this expense, the one incurred through loss of time, the steamer being laid up in drydock for weeks and weeks in order to have the new part fitted in, is very heavy indeed.

I now come to an application of thermit which differs mate-

rially from the ones I had the privilege of demonstrating to you up to now. That is welding wrought-iron pipes.

Of course the heat of the iron if applied direct would destroy the thin walls of the pipe. Here, then, the corundum slag created on the top of the mass in the crucible comes into play. On being poured it has the properties of adhering instantaneously in a thin layer to any object that it comes in contact with and of being impervious to liquid thermit iron. The sequence of operation is therefore changed and the slag is made to flow out before the iron. The reaction takes place in a crucible with a solid bottom, from which the contents are poured over the rim.

To butt-weld the pipes the ends must be made to fit accurately on to each other and must be made bright with a file or emery paper. The two pipes are then firmly pressed together by the clamping apparatus, and the sheet-iron mold, well surrounded with moist sand, is attached. After pouring the liquid contents of the crucible welding temperature will take place within a minute or two. The clamps then want tightening one turn of the screw and the weld is complete. The mold box is removed almost at once and can be used several times. The surrounding mass, containing the iron between the layers of slag, like the yolk in the white of an egg, is easily removed with a hammer. Such welds will stand pressure of hundreds of atmospheres; as a matter of fact, as much as the pipe itself. About 30,000 to 40,000 pipe joints have been welded by this method, the advantages of which are, shortly, that the operation can take place anywhere, and that it is cheaper than a solid flange joint. The dimensions of the molds have been carefully worked out and tabulated for every size of wrought-iron pipe up to six inches diameter. Any workman will be able to make such welds after very short practice by carefully observing the few rules and directions printed in the pamphlets.

One of my associates, Mr. Mathesius, has specially devoted himself to studies concerning the improvement of iron and steel castings. These are obtained by introducing the thermit below the surface of the bath, and so producing a high temperature in one place. A box containing the thermit is fastened to an iron rod and held down on the bottom of the ladle.

For cast iron, and, in some cases, for steel, a special thermit is used which gives off an alloy of iron with titanium, so that the titanium enters the liquid metal. The reaction takes place all through the contents of the ladle and thoroughly stirs them up in the space of a minute or two. Gases and particles of slag are driven upward so that the fluidity of the iron is increased. An increase of the temperature does not in reality take place, as the proportion of added thermit is only one-quarter to one-sixteenth per cent. of the total contents of the ladle. The effect of the titanium is to bind small quantities of nitrogen, to increase the fluidity of the cast iron, and to produce a finer grain.

Another application of the so-called "box reaction" is important for steel castings, and especially for casting large steel ingots, to prevent the familiar phenomenon of piping. In the heads of such blocks hollow spaces are found, which mostly cause 30 to 40 per cent. of loss.

The thermit process, as used for this purpose, consists in introducing a box of so-called anti-piping thermit into a block with the aid of an iron rod, in exactly the same way as described before. According to the size of the block, the box is suspended about three feet. The reaction is completed in this case in a few seconds. The box is introduced, of course, only after the piping has been formed. The head layer, which has already become solid, is broken through for this purpose. Immediately after the reaction is completed, steel, which is held in readiness for this purpose, is poured into the open hole. The method is really very simple, and one learns very quickly at which time to introduce the box. Moreover, it is very cheap, only about ten pounds of thermit being required for blocks of ten to twenty tons weight. After the treatment, relatively very small flaws were found, and only in the upper part of the block, so that the loss is only a very few per cent.

The method has also been applied for very large steel castings to revive steel which had become plastic in the runners. In this the anti-piping thermit is placed at the bottom of some risers, in an annular box with concentric walls, containing about 2½ pounds of thermit.

The difficult operation of casting long stern posts of vessels can be facilitated by inserting in several places boxes of this thermit. On account of the long way steel has to travel, it has a tendency to grow plastic. But coming into contact with thermit, its temperature, and thereby its fluidity, is revived.

SPECIAL ALLOYS FOR IMPROVING STEEL.

Of the numerous alloys now in use for improving carbon steel, the following deserve special mention, as all of them are produced in quantity, and, therefore, present commercial products, which may be bought in the present market: (1) ferronickel, (2) ferrochrome, (3) ferrocobalt, (4) ferrochrome nickel, (5) ferrotungsten nickel, (6) ferrosodium, (7) ferroaluminum, (8) ferrotungsten, (9) ferrosilicon, (10) ferrophosphorus, (11) ferromolybdenum, (12) ferrotitanium, (13) ferromanganese, (14) ferrovanadium, (15) ferroboron, (16) ferrouranium, (17) molybdenum nickel, (18) copper silicon. These alloys have become prominent in later years, and are employed in the production of steel containing a definite percentage of the respective alloying metals. They are added to the molten steel either in lump or powder form, but preferably enclosed in cast-iron tubes, and are thus inserted into the steel bath with perfect assurance of incorporating the whole amount of the charges made. Each of the compound steels thus obtained possesses peculiar and characteristic properties which make it fit for a special purpose, and almost all are known to improve the toughness and elongation of carbon-steel, while some of them impart a great hardness and elasticity to that substance. As to the nature of alloys in general, it must be remembered that they are comparable in a degree to "solutions," and are distinguished in chemistry as "undetermined compounds." In many respects they show the average deportment of the metals from which they arise, but, by combining the various metals, alloys of the desired properties can be produced, and on this behavior is based their technical application. To cite a familiar example, gold and silver, which are very soft when in pure condition, may be essentially hardened by alloying them with copper; and copper itself is ren-

dered harder by alloying it with zinc.—Dr. J. Ohly in "Mines and Minerals."

ADVANTAGES OF SUPERHEATED STEAM.

The theoretical advantages of superheated steam have been fully realized for some time, but practical difficulties connected with its use in engines of the piston and cylinder type have so far debarred its general use. Notwithstanding all the efforts made to insure high steam economy during fully fifty years, there is at the present time no vessel of importance fitted with superheaters. A series of interesting trials upon a turbine of the De Laval type has recently been conducted at Dresden, and the results are embodied in a contribution to a German technical paper. The tests have continued during the past two years upon a 30-horsepower De Laval turbine in the laboratory with steam of 500 degrees centigrade superheat. The consumption of steam was accurately determined by condensing all the steam which passed through the turbine. Heat losses were provided against as fully as practicable by jacketing the apparatus. The turbine was arranged to be run at a speed of 20,000 revolutions per minute, reduced by gearing to 2,000 revolutions of the shaft upon which the brake was placed. The machine was operated by steam of a pressure of 6 kilograms per square centimeter (85.33 pounds per square inch), and when exhausting against the pressure of the atmosphere was rated to develop 30 horsepower. An interesting featu re of the tests is the use of various nozzles, experiments having been made with diverging and converging nozzles, using bronze and steel as materials. Broadly speaking, the results show a notable economy in steam consumption. The diverging nozzle gives better results than the converging type, and steel was found more advantageous material than bronze. — "Scientific American" Supp.

NICKEL-STEEL BOILER TUBES.

An interesting paper on "Non-Corrosive Nickel-Steel Boiler Tubes" was read by Mr. Albert Ladd Colby at the recent annual meeting of the American Society of Naval Architects and Marine

Engineers. His paper dealt with the successful manufacture in America, on a commercial basis, of a new boiler tube, practically non-corrosive and of much higher tensile strength than the tube now in use. These desirable properties are obtained by introducing, during the manufacture of the steel, a large percentage of nickel. He exhibited numerous samples of the tubes, 30 per cent. nickel, made by the Shelby Company. The tubes were first made commercially in France and Germany. Since then they have been under practical trial in the French, German and Dutch Navies with gratifying results. Mr. Colby submitted results of a series of exhaustive tests of the tubes made by Mr. A. F. Yarrow, of England. "The consensus of opinion abroad is that these tubes will last at least two and one-third times longer than mild carbon-steel tubes. The American tubes, having only just been successfully manufactured, have not yet been submitted to a practical trial for marine boilers. It is perfectly safe, however, to state that the American tube will have as long a life as the foreign tube, and probably a somewhat longer life, from the fact that the foreign tubes contain from 23 to 25 per cent. of nickel, whereas in the manufacture of the American tubes it was decided to use a 30 per cent. nickel-steel, so as to still further increase the resistance of the tubes to corrosion.

"The American tubes have recently been put under trial in stationary boilers, locomotive boilers, automobile boilers, and in the very near future they will be given a practical trial by the Navy, both for boilers and condensers, and possibly also for superheaters. The exhibits include 30 per cent. nickel-steel tubes of American manufacture, varying from $\frac{5}{8}$ to 4 inches outside diameter, and of the usual range in gauges. They also include "beading," "expanding" and "flattening" tests, which show that they more than meet all the manipulating tests required by the Navy Bureau of steam engineering. Among foreign samples in the exhibit is one of the ordinary carbon-steel tubes, and it is interesting to compare the marked corrosion of this tube with the 25 per cent. French nickel-steel tubes, which show no evidence whatever of having corroded. Increased cost is the only

disadvantage with these tubes, but they are offered here at lower cost than is demanded by the French and German makers.

"Advantages of the high nickel-steel tube are: 1. High tensile strength in comparison with that of mild carbon steel. 2. Entire absence of brittleness, as evidenced by the severe manipulating tests which they will stand. 3. Higher elastic limit, which prevents leaks where the ends of the tubes pass through the flue-sheets. Expansion of the flue-sheets, when heated, compresses the tube at the point where it passes through the flue-sheet, and in the mild carbon-steel tube, with its low elastic limit, this causes a permanent deformation, which results in leakage and necessitates expanding the tubes. High nickel-steel, with its much higher elastic limit, resists this compression. 4. Resistance to corrosion, as proved conclusively by Mr. Yarrow's tests, which are before you. 5. Saving in weight made possible by the lighter gauges of the nickel-steel tubes, which are perfectly safe owing to the increased tensile strength. There is a saving in weight in stationary boilers of over two tons in a boiler installation of 500 H.P., and no less than 8.6 tons in an installation of 2,000 H.P. In the case of the torpedo-boat destroyer *Hopkins*, which was taken as a standard, the adoption of a No. 14 gauge tube in place of the tube now in use of No. 11 gauge, makes a saving in weight of no less than 24,881 pounds, or 11.1 tons, and similarly, in the battleships *Rhode Island* and *New Jersey*, the saving in weight amounts to 85,093 pounds, or no less than 38 tons.

"It is unnecessary for me to call the attention of marine engineers to the importance of these figures; nor do I need to more than refer to the practical advantage of the use of a lighter gauge in the saving of fuel due to the extra steaming efficiency of a boiler equipped with lighter-gauged tubes. The only disadvantage of these tubes is their cost, which per pound is about three times that of mild carbon steel tubes. The 1⅛-inch tubes used in torpedo-boat destroyers which now cost 15 cents a pound will, if of nickel-steel, cost 45 cents a pound, and for the 2 and 4-inch tubes used in battleships, now costing 12 cents a pound,

the price will be 35 cents a pound. This difference in cost is reduced in the first place by salvage that can be obtained in the sale of the nickel-steel tubes when they are finally taken out of the boiler. Old tubes can be sold at 6.4 cents a pound. The costs per pound are, furthermore, not directly comparable, owing to the fact that less weight of the nickel-steel tubes is purchased, on account of their lighter gauges, and when it is borne in mind that these tubes have a life of at least two and one-third times that of the mild carbon-steel, the increased cost is really more than offset by the expenses incident to the more frequent retubing of the boiler when mild carbon-steel tubes are used; this to say nothing of the expense and annoyance of putting vessels more frequently out of commission for repairs of boilers."

BREAKDOWNS IN BRITISH NAVY.

One of the features of the recent British Navy maneuvers, which proved most unpleasant and unsatisfactory to British observers, was the numerous small defects in the machinery, causing breakdowns, and the temporary withdrawal of vessels from the exercises. In all, some twelve battleships and cruisers were compelled to undergo repairs, marring the success of the maneuvers and causing considerable discussion in consequence. What would be the consequences in case of actual warfare instead of maneuvers are unpleasant thoughts for the Englishman. English opinion as to the causes for the accidents seems to be that they cannot be attributed to the undermanning of the vessels, as the warships have about as many men aboard as the Atlantic steamers, upon which a breakdown is almost an unheard-of thing, but to the system of employment and inspection of engineers in vogue in the British Navy.—"The Nautical Gazette."

OIL FUEL.

The Admiralty evidently contemplates the extensive adoption of oil fuel for warships in the near future. Three oil gunboats at Portsmouth have been transformed into oil hulks, their en-

gines, boilers, guns and everything below deck having been removed and replaced by tanks for oil, with a pump by which the fluid may be raised for filling oil tanks on battleships. Experiments are still being made on board the destroyer *Surly*, and the destroyer *Spiteful* is being prepared for a series of trials. The old battleship *Sultan* is having her furnaces adapted for oil burning, and it is proposed to carry out a series of experiments on her with various kinds of oil and different modes of combustion. Classes of stokers will also be trained to use the liquid fuel, so as to produce the maximum of heat with the minimum of smoke. The battleships *Mars* and *Hannibal*, on returning to Portsmouth, will have the whole of their furnaces adapted for oil. At present they use coal in half the furnaces. The oil furnaces have so far given encouraging results, and the extension of the system is no doubt the result of the experiences gained in the summer maneuvers, during which the oil fuel was in constant use.—Ex.

[The *Mars* and *Hannibal* are of 15,140 tons displacement, 12,000 I.H.P. and 18 knots].—EDITOR.

In presenting the naval estimates, Lord Selborne said:

"The experiments with oil fuel have continued without a day's intermission, and it can be accurately stated that in no country has greater attention been given to this subject or the experiments been more exhaustive. The progress has been slow, but sure; it is not a matter which can be hurried; the great difficulties connected with the satisfactory use of oil in ships of war can only be overcome by patience and continual experiment; the experience gained with the *Mars* and *Hannibal* in the Channel Fleet with their cylindrical boilers has been utilized in respect of the Belleville boilers of the *Bedford*, which has now been commissioned for service in the Channel Fleet. Simultaneously with the experiments in the use of oil fuel, the question of its storage and supply is being carefully studied."

SHIPS.

UNITED STATES.

Charleston.—The protected cruiser *Charleston* was successfully launched from the yards of her builders, the Newport News Shipbuilding and Dry Dock Company, Newport News, Va., on January 23.

The *Charleston* is an improvement on the cruiser *Olympia*. The principal dimensions, armament and protection of the vessel are: Length on load water line, 424 feet; breadth (extreme), 66 feet; trial displacement, 9,700 tons; mean draught at normal displacement, 23 feet six inches; engines, twin screw, indicated horsepower, 2,100; speed, 22 knots; normal coal supply, 550 tons; coal bunker capacity, 1,500 tons.

Armament.—Fourteen 6-inch rapid-fire guns, eighteen 14-pound rapid-fire guns, twelve 3-pound rapid-fire guns, four 1-pound automatic guns, eight 1-pound rapid-fire guns, two 1-pound rapid-fire field guns, two machine guns, .30 caliber; eight automatic guns, .30 caliber.

Protection. — Main side armor, 4 inches; lower casemate armor, 4 inches; 6-inch gun protection, 4 inches; conning tower and shield, 5 inches; signal tower, 4 inches; splinter bulkheads, 2 inches; protective deck, 2½ inches. She has two military masts with fighting tops. Additional platforms are built on the masts to accommodate two searchlights. Electric ammunition hoists will supply the guns.

Four smokestacks, 76 feet 6 inches high, provide draft for sixteen straight water-tube boilers, located in four watertight compartments, and, together with the engines, protected by the side armor, sloping-deck armor and coal bunkers. Wherever wood has been used in construction it is fireproof. All the latest and best improvements in construction and equipment have been provided for the accommodation and comfort of the officers and crew. The vessel, when completed, will have a com-

plement of 39 officers and 525 men, and also quarters for a flag officer.—"Army and Navy Journal."

Virginia.—This battleship, one of the Class of the same name, is to be launched from the works of the Newport News Shipbuilding and Dry Dock Company, Newport News, Va., on April 5, and will be the third large naval vessel launched from the same works within the last half year.

Principal Characteristics.—Length on load water line, 435 feet; breadth (extreme) at load water line, 76 feet 10 inches; trial displacement, about 15,000 tons; I.H.P., designed, 19,000; speed, designed, 19 knots.

Armament.—Four 12-inch breech-loading rifles, of 40 calibers in length; eight 8-inch breech-loading rifles, of 45 calibers in length; twelve 6-inch breech-loading rapid-fire rifles, of 50 calibers in length; twelve 3-inch (14-pounder) rapid-fire guns, of 50 calibers in length; twelve 3-pounder semi-automatic guns; four 1-pounder heavy automatic guns; four 1-pounder heavy rapid-fire guns; two 3-inch field pieces; two machine guns, .30 caliber; six automatic guns, .30 caliber; two submerged torpedo tubes.

Boilers.—Twenty-four Niclausse, in six compartments, G. S., 1,280 square feet; H. S., 57,534 square feet.

Appropriation of 1904.—NEW VESSELS PROVIDED FOR.—The appropriation bill for the continuation of the building program for the Navy provides for the following vessels:

One battleship, 16,000 tons displacement. Cost, hull and machinery, $4,400,000; armor and armament, $3,320,857; total, $7,720,857.

Two armored cruisers, 14,500 tons displacement. Cost, hull and machinery, $4,400,000 each; armor and armament, $2,055,038 each; total, $6,455,038 each; total, two, $12,910,076.

Three scout cruisers, 3,750 tons displacement. Cost, hull and machinery, $1,800,000 each; armament and equipment, $400,000 each; total, $2,200,000 each; total, three, $6,600,000.

Two colliers, 12,000 tons displacement. Cost, each, $1,250,000; total, two, $2,500,000.

Grand total for new vessels, $29,730,933.

The total sum for the Navy for which appropriation is made amounts to $97,000,000 in round numbers, an increase of about $15,123,000 over the appropriation of last year.

In presenting this bill Senator Hale produced data which gives the *Relative Order of Warship Strength*, "At present," and "As would be the case were vessels building now completed," in which the United States advances from fifth to third place among the naval powers, the order and tonnage in the two cases being:

1. Great Britain, .	1,516,040	Great Britain, .	1,867,250
2. France, . .	576,108	France, . .	755,757
3. Russia, . .	416,158	United States, .	616,275
4. Germany, .	387,874	Russia, . .	558,432
5. United States, .	294,405	Germany, . .	505,619
6. Italy, . .	258,838	Italy, . . .	329,257
7. Japan, . .	243,586	Japan, . . .	253,681
8. Austria, . .	93,913	Austria, . .	149,833

The vessels of greater than 1,000 tons displacement now under construction are:

1 battleship, 11,500 tons, 18 knots.

5 battleships, 15,000 tons, 19 knots (2 unsheathed, 14,600 tons).

5 battleships, 16,000 tons, 18 knots.

2 battleships, 13,000 tons, 17 knots.

6 armored cruisers, 13,800 tons, 22 knots.

2 armored cruisers, 14,500 tons, 22 knots.

3 protected cruisers, 9,700 tons, 22 knots.

6 protected cruisers, 3,200 tons, 16½ knots.

2 gunboats, 1,085 tons, 12 knots.

AUSTRO-HUNGARY.

St. George.—Armored cruiser; successfully launched from the Navy Yard at Pola.

General characteristics: Length, 383 feet 9 inches; beam, 61 feet 7 inches; draught, 21 feet 3 inches; displacement, 7,300 tons; I.H.P. (designed), 13,000; speed (designed), 21 knots.

Armament: Two 9.5-inch; five 7.5-inch; four 5.9-inch R.F.; twenty-five smaller guns; four torpedo tubes.

ENGLAND.

Navy Estimates for 1904-5.—The total of this year's Navy estimates is £36,889,500 ($179,283,000), an increase of £1,124,000 ($5,462,600), over last year's estimates. Of this sum, £11,654,176 ($56,639,300) is to be devoted to new construction, and the vessels authorized are: Two battleships, four armored cruisers, fourteen destroyers and ten submarines.

The battleships are to be known as the *Lord Nelson* Class, and, though no details are given, it is understood that they will be of 18,000 tons displacement and will cost about $7,776,000 each.

This year's estimates show a continuation of the Admiralty's policy to make the British Navy strong enough to cope with the navies of any two powers and to insure the security of England's maritime and colonial interests.

Medusa and Medea.—COMPARATIVE TRIALS FROM ENGLAND TO GIBRALTAR AND RETURN. — In a recent number we made mention of comparative trials in progress between the British cruisers *Medusa* and *Medea* for the purpose of testing their boilers, the former being equipped with Dürr and the latter with Yarrow boilers. On the results of these trials, which took place from England to Gibraltar and return, the following particulars were furnished us by the Düsseldorf-Ratinger Water-Tube Boiler Company, formerly Dürr & Company, which particulars are based on personal inquiries by that firm, the British Admiralty declining to give out information.

The trip out to Gibraltar was made with 5,000 I.H.P., all boilers being under steam. The return trip was made against time with but four boilers, this being one-half the boiler capacity. Both vessels had orders to steam back to England at their best speed. The *Medusa* developed 5,160 I.H.P. during the first two hours; this is at the rate of 5.2 I.H.P. per square meter heating surface, or 195 I.H.P. per square meter grate surface. With this performance she ran well ahead of the *Medea*, the latter evidently making an unsuccessful effort to follow.

When the *Medusa* had a lead of about five nautical miles one of the auxiliaries (Said to be a forced-draft blower.—EDITOR.) on the *Medea* broke down. After being forty-eight hours under way

nothing more could be seen of the *Medea* from the *Medusa*, and the work in the boiler rooms of the *Medusa* slackened considerably. Ten hours before the end of the trip the atmosphere became clear, and the *Medea* again could be seen about eight nautical miles astern. Fires were ordered to be cleaned on the *Medusa*, meanwhile the *Medea* having come up to within three nautical miles, although she could not get nearer than this, as the fires on the *Medusa* were now in good condition, and the latter increased her lead and won the race by ten minutes. According to some British journals, the time given is three minutes; others give five minutes, this probably being based on some method of time allowance at the start, or other arrangement to that effect.

During the last three hours the *Medusa's* engines developed 4,800 I.H.P., or about 4.83 I.H.P. per square meter of heating surface. The average I.H.P. during the 64-hour trial developed by the Dürr boilers was 4,347; this is 4.4 I.H.P. per square meter of heating surface, which can be considered a very satisfactory result.

The coal consumption, including auxiliaries, was .97 kilogram per I.H.P. per hour.

Contrary to reports in certain British papers, the Dürr boilers developed no leaks during the entire trial, neither in the tube connections nor in the seams. * * *

The following are the results of a trial of the *Medusa* in May, 1903, at which one of the representatives of Dürr & Co. was present:

Number of boilers	8
Heating surface (1,986 square meters), square feet	21,376
Grate surface (52.8 square meters), square feet	568.3
Air pressure in boiler room (8 millimeters water), inches	.315
Indicated horsepower	7,347
Coal consumption per hour—includes that for all auxiliaries (.92 kilogram)—pounds	2.028
Coal burned (per square meter grate surface, 128 kilograms), pounds per square foot	2.621
Evaporation per one kilogram of coal, kilogram water	8.2
Evaporation (per square meter heating surface, 27.9 kilograms water), per square foot of heating surface, pound	5.714

—Translated from the "Zeitschrift," January 16, 1904.

NOTE.—The *Medusa* was undergoing further trials in January, a thirty-hour trial followed by others.

The *Medea*, after certain modifications in her boilers, following the above run from Gibraltar, will go to Malta and return. —EDITOR.

Africa, Britannia, Hibernia.—MACHINERY CONTRACTS.—The Admiralty have now arranged the contracts for the machinery of the three battleships which have been ordered from the government dock yards instead of being given out to contract. The *Africa*, to be built at the Chatham dock yard, is to be engined by John Brown & Co., Clydebank; the machinery for the *Hibernia*, laid down at Devonport, will be supplied by Harland & Wolff, Belfast, and the engines and boilers of the *Britannia*, to be constructed at Portsmouth, will be supplied by Humphreys, Tennant & Co., London. These battleships are of the same type as those of the *King Edward VII* Class, and the low tenders sent in for the machinery by the successful firms are explained by the fact that each has already in course of construction machinery of the same dimensions and type, so that their patterns, jigs, etc., do not require to be made anew. Thus John Brown & Co. have on hand the engines of the *Hindustan;* Harland & Wolff those of the *King Edward VII*, and Humyhreys & Tennant those of the *New Zealand*. The engines are of the four-cylinder, triple-expansion type, the high-pressure cylinders being 38 inches, the intermediate 60 inches and the two low-pressure cylinders 67 inches in diameter, with a stroke of 48 inches. The power of 18,000 I.H.P. is to be realized with a piston speed of 960 feet per minute. As to the boilers, one-fifth of the power will be got from generators of the cylindrical type, and the remaining four-fifths from Babcock & Wilcox water-tube boilers, as is the case with the *Commonwealth*, building at Fairfield; the *Dominion*, building at Barrow-in-Furness, and the *Hindustan*, just launched here.—"Marine Review."

(Each ship will have eighteen units of these boilers—total heating surface, 45,000 square feet; grate surface, 1,250 square feet.—EDITOR.)

Hindustan.—The battleship *Hindustan* was launched on De-

cember 19 from the John Brown yards at Clydebank. Contract, September 18, 1902, and keel laid October 25, 1902.

The ship has the following dimensions: Length over all, 424 feet 9 inches; beam, 78 feet 1 inch; depth, 26 feet 9 inches; displacement, 16,350 tons; indicated horsepower, 18,000; speed, 18½–19 knots; boilers, ⅓ Scotch, ⅔ Babcock & Wilcox.

The armament consists of four 12-inch guns in two 12-inch barbette turrets, barbettes being 14 inches thick, four 9.2-inch guns in turrets of 6 and 7-inch armor thickness, in the main battery; of ten 6-inch, eighteen 3-inch, fourteen 1⅞-inch R.F. and six machine guns, in the secondary; and four submerged torpedo tubes. The normal coal-bunker capacity is 950 tons, maximum 2,000 tons.

The important feature wherein the vessels of this type differ from their predecessors is that they mount, in addition to four 12-inch guns, four guns of 9.2-inch caliber, in secondary casemates at the corners of the citadel, with ten 6-inch guns in a box battery within the citadel. The armor extends from 5 feet below the water line right up to the upper deck, the successive strakes from the water line being 9 inches, 8 inches and 7 inches in thickness. The *King Edward VII* Class, of which eight have now been ordered, does not mark finality, if, indeed, it conforms to present-day conceptions, especially in the matter of gun power.

Cadmus.—The *Cadmus*, sloop, returned to Sheerness Dockyard yesterday upon the successful completion of her official steam trials, particulars of which are appended: Thirty hours' trial at three-fourteenths her *maximum* power. Pressure of steam in boilers, 166 pounds; at engines, 160 pounds; vacuum, starboard, 26.5 inches; port, 28 inches; revolutions, starboard, 114; port, 114; aggregate I.H.P., 327; coal consumption per I.H.P. per hour, 2.16 pounds; speed, 6 knots. Thirty hours' trial at five-sevenths *maximum* power. Pressure of steam in boilers, 195 pounds; at engines, 186 pounds; vacuum, starboard, 27 inches; port, 27.5 inches; revolutions, starboard, 175; port, 176; aggregate I.H.P., 1,061; coal consumption per I.H.P. per hour, 1.83 pounds; speed, 11 knots. Eight-hours' full power

trial. Pressure of steam in boilers, 217 pounds; at engines, 204 pounds; vacuum—starboard, 26.1 inches; port, 27.1 inches; revolutions, starboard, 194; port, 194; aggregate I.H.P., 1,424; coal consumption per I.H.P. per hour, 1.98 pounds; speed, 13.4 knots. The contract with J. S. White & Co., of Cowes, was for 1,400 I.H.P. The boilers of the *Cadmus* are of the Niclausse type.—"Times," London.

Queen.—The first-class battleship *Queen* has completed her trials successfully. During the thirty-hours' run at one-fifth power the ship experienced exceptionally heavy weather. The results were as follows: Steam in boilers, 205 pounds; steam at engines, 201 pounds; high-pressure receiver, 175 pounds starboard and 164 pounds port; vacuum, 27 inches starboard and 27.3 inches port; revolutions per minute, 69 5 starboard and 68.3 port; I.H.P., high pressure, 444 starboard and 535 port; intermediate, 495 starboard and 527 port; low, 581 starboard and 476 port; total I.H.P., 1,520 starboard and 1,538 port; gross I.H.P., 3,058; coal consumption per hour, 5,630 pounds; coal consumption per I.H.P. per hour, 1.84 pounds. The average speed was 11.3 knots. The result of the thirty-hours' trial at four-fifths power was also very satisfactory. The ship made four runs on the deep-sea course off the Cornish coast, and obtained a mean speed of 16.94 knots. The following were the mean results: Steam in boilers, 232 pounds; steam at engines, 223 pounds starboard and 222 pounds port; vacuum, 25 inches starboard and 26 inches port; revolutions, 106.2 per minute starboard and 106.5 per minute port; I.H.P., 5,860 starboard and 5,810 port; total I.H.P, 11,670; coal consumption per I.H.P. per hour, 1.61 pounds. During her eight-hours' full-speed trial she attained a speed of 18.4 knots. The mean results were as follows: Steam in boilers, 243 pounds; steam at engines, starboard 231, port, 227 pounds; air pressure in stokeholds, 0.5 inch; vacuum, starboard, 26.3 inches, port, 26.7 inches; revolutions, starboard, 116.4, port, 115.9; gross I.H.P., 15,556; coal consumption per I.H.P. per hour, 1.76 pounds. The ship will, after her machinery has been opened up, undergo another trial, by

direction of the Admiralty, as a further test of machinery.—"J. R. U. S. I." (See Steam Trials.)

Exe.—The torpedo-boat destroyer *Exe* has completed her trial successfully off the Tyne. The coal-consumption trial was for the purpose of determining the amount of coal that would be burnt per hour at 13 knots, this being the most economical speed for this class of boat. This trial was of twelve hours' duration, and the first part consisted of six runs on the measured mile to find out the number of revolutions required for 13 knots. The mean results of the run were 161 revolutions for 13.34 knots, the I.H.P. developed being 700, one-tenth only of the 7,000 at full speed of 25½ knots. Keeping up 160 revolutions for the remainder of the twelve hours, the amount of coal burnt was 5½ tons for the whole time. From this the coal consumption was deduced and worked out at 1.45 pounds per I.H.P. per hour. The bunkers hold 130 tons, so that at 13 knots the radius of action is 3,000 miles approximately, which proves that the boilers, which are of the Reed type, are very economical. Two boilers only were used, and the steam pressure was kept at 160 pounds per square inch. The vacuum in the condensers was 26 inches, and the machinery worked satisfactorily. The *Exe* will probably be delivered at Portsmouth by the end of January. Her first full-speed trial was unsuccessful, owing to a hot crank bearing. On the day of the second trial the sea was moderately rough, with a stiff northwest wind; but the results were satisfactory, although, as in the case of the *Erne*, recently, the metallic packing in the high-pressure glands was by no means tight, and this will have to be remedied. The six runs on the mile gave a mean speed of 25.33 knots, with 348.98 revolutions per minute, and 7,129 I.H.P., from which was deduced the fact that to get the requisite 25.5 knots for the remaining three hours the revolutions must be 351.32.

On the completion of the trial the means were found to be 25.64 knots, 353.2 revolutions and 7,147 I.H.P. The average steam pressure was 249 pounds per square inch; air pressure in the stokeholds, 2.3 inches, and vacuum 25 inches. The ship was loaded to 564 tons displacement, with a mean draught of water of 8 feet 4½ inches on leaving the harbor, and on returning it

was reduced to 521 tons displacement and 8 feet 2 inches mean draught, this giving a mean displacement of about 540 tons, the designed load.—"J. R. U. S. I." (See Steam Trials.)

Foyle.—The official trials of the destroyer *Foyle* have been successfully completed. A successful four-hours' full-power coal-consumption trial had previously been made, and at the official full-speed trial the vessel maintained a speed for four hours' continuous running of 25.65 knots. On both occasions the vessel was run in a fully loaded condition. All the trials for steering, stopping and starting were also successfully completed. The *Foyle* will be hastened forward for commission.—"J. R. U. S. I." (See Steam Trials.)

Eden.—H. M. torpedo-boat destroyer *Eden*, fitted with Parsons steam turbines, has recently completed her official full-speed trials. The *Eden* is one of the latest 25½-knot type of torpedo-boat destroyers, her dimensions being 220 feet by 23 feet 6 inches by 13 feet 9 inches. On the official four-hours' full-speed trial, with over 125 tons load on board, the vessel easily attained the speed of 26.099 knots for the first hour and 26.229 knots for the last three hours, the guaranteed speed being 25½ knots. The result of a previous four hours' full-speed coal-consumption trial was very satisfactory, the coal consumption on this trial being within the amount stipulated in the contract. The main propelling machinery, which was constructed at the Turbinia Works, Wallsend-on-Tyne, consists of three turbines—one high-pressure and two low-pressure turbines, each driving separate shafts, with two propellers on each shaft. Inside the exhaust casing of each of the low-pressure turbines a reversing turbine is fitted. In view of the great variation in the horsepower required in modern war vessels, two additional cruising turbines are permanently coupled to the shafts of the main low-pressure turbines. When working at reduced power, the steam from the boilers passes through the cruising turbines in series and thence to the main turbines; by this means a high ratio of expansion of the steam at all lower speeds is obtained, and the loss by throttling of the steam is avoided. The hull and boilers were constructed by R. and W.

Hawthorne, Leslie and Co., to the order of the Parsons Marine Steam Turbine Company.—"Engineering."

Prince of Wales.—This first class battleship, built at Chatham dockyard has just completed all her official trials with very satisfactory results. The vessel is a sister ship to H.M.S. *Queen*, the trials of which were completed recently; but the boilers, in the case of the *Prince of Wales*, are of the Belleville type. On the thirty-hours' trial, at one-fifth full power, with eight out of the twenty boilers alight, the indicated horsepower developed was 3,128, at 66½ revolutions, with a steam pressure of 220 pounds, and on the three-fourths power trial, 11,669 indicated horsepower at 106 revolutions. The final trial at full power gave 15,364 indicated horsepower, with 113 revolutions. A low coal consumption, which, of course, is an important feature of such trials, was maintained in all cases under natural draft, while the water saved over the Admiralty allowance was 10 tons and 5 tons in three-fourths and full-power trials respectively. Her machinery and Belleville boilers were constructed by the Greenock Foundry Co. (Scott & Co.). The vessel is 400 by 75 by 26.9 feet in mean draught, and of 15,000 tons displacement. She is armed with four 12-inch, twelve 6-inch, and twenty-eight other guns of smaller caliber.—"Steamship." (See Steam Trials.)

Diamond.—Third-class protected cruiser. Was launched January 6th at the works of Laird and Cammell, Birkenhead.

Principal characteristics: Length, 360 feet; beam, 40 feet; draught, 14.5 feet; displacement, 3,000 tons; protective deck, entire length of vessel, 2 inches in thickness; two vertical, triple-expansion, four-cylinder engines; water-tube boilers; indicated horsepower under forced draft, 9,800; speed, 21¾ knots; coal capacity, normal, 300 tons.

Armament: Twelve 4-inch Q. F.; eight 3-pounders Q. F.; two Maxims; two 18-inch torpedo tubes.

Amethyst.—The third-class cruiser *Amethyst* was launched from the yard of Armstrong, Whitworth and Co., at Elswick, New-castle-on-Tyne. Her dimensions are as follows: Length between perpendiculars, 360 feet; beam, 40 feet; displacement, 3,000 tons, with a mean draught of 14 feet 6 inches. Her arma-

ment will consist of twelve 4-inch quick-firing guns, eight 3-pounder quick-firing guns, two Maxims and two 18-inch torpedo tubes. She will have a 2-inch steel protected deck. She is the first ship, with the exception of the two destroyers *Velox* and *Eden*, to be fitted with turbines of the Parsons compound type. She will have three screws, driven by turbines, which, under forced draft, are to develop 9,500 I.H.P., to give a speed of 21.8 knots. Special turbines are to be fitted for going astern; and to secure economy at cruising speeds, two cruising turbines will also be fitted, in addition to the high-speed one. The boilers are to be of the modified Yarrow type.

Hampshire, Carnarvon, Antrim, Roxburgh.—Four of these armored cruisers of the improved *County* class have been launched recently—*Hampshire*, from Elswick yard, September 24th; *Carnarvon*, from Beardmore yard, Govan-on-Clyde, October 7th; *Antrim*, from J. Brown & Co. yard, Clydebank, October 8th; *Roxburgh*, from London and Glasgow yard, January 19th.

The dimensions of all four of these ships are the same and are as follows: Length between perpendiculars, 450 feet; beam, molded, 68 feet 6 inches; depth, molded, to upper deck, 38 feet 6 inches; mean load draft, 24 feet 9 inches; displacement at load draft, 10,700 tons; I.H.P., designed, 21,000; speed, designed, 22½ knots.

The hull is subdivided into watertight compartments, a double bottom extending the entire length of the machinery and magazine spaces forward and aft. The lower or protective deck is of the turtle-back type, extending all fore-and-aft, and at side forms a shelf supporting the armor. Under this deck all machinery, magazines and auxiliaries are placed, the deck being intended to protect all vital parts of the ship. The armor belt, 6 inches thick, of specially-hardened steel, extends from the lower to the main deck at sides for a distance of about 250 feet in wake of the machinery spaces and magazines. At the forward end the armor is reduced to 4½ inches thick, extending for about 50 feet; thence to the stem the sides are protected by nickel-steel plates 2 inches thick, the bottom edges of which are carried down forward in line with protective turtle-back deck, giving additional stiffening for

ramming purposes. At the after end of the main armor belt a transverse armor bulkhead is carried across the ship, between the lower and main decks, connecting the ends of the belt armor. The main deck over the armored citadel of the ship is specially strengthened, having two thicknesses of plating. The coal bunkers are placed along each side, extending the whole length of the engine and boiler rooms, from double bottom to main deck, forming additional protection to machinery. The armament will consist of two 7.5-inch quick-firing guns of latest pattern, mounted in barbettes, one on forecastle and one on upper deck aft; ten 6-inch quick-firing guns in casemates on the broadsides (four of which can be trained right ahead and four right astern), the barbettes and casemates being 6 inches in thickness; two 12-pounder quick-firing guns, twenty-three 3-pounder quick-firing guns, two Maxim guns and two submerged torpedo tubes. The machinery, which will be supplied by the builders, consists of two sets of triple-expansion, four-cylinder engines, each set being arranged in pairs, having the cranks of each pair directly opposite to each other, and the cranks of the forward pair placed at right angles to those of the after pair. The diameters of cylinders and order of their positions from forward are: Low pressure, 73½ inches; high pressure, 41½ inches; intermediate pressure, 65½ inches; low pressure, 73½ inches, all having a stroke of 42 inches. All the cylinders are fitted with steam jackets. The liners of the high-pressure and intermediate-pressure cylinders are of forged steel; those for the low-pressure cylinders are of cast iron. There are four large condensers for the main and auxiliary engines. Each of the condensers is fitted with sluice valves, on the inlet and outlet of the circulating water, and also on the exhaust branches, so that any condenser may be repaired while the others are at work. There are four boiler rooms, and these ships are supplied with one group of cylindrical boilers and three groups of water-tube boilers, designed for a working pressure of about 210 pounds. On the *Roxburgh*, in the after boiler room, the cylindrical boilers are fitted. These will be worked on the closed ash-pit system of forced draft, the doors and fittings for which have been made and supplied by Howden and Co. on their well-

known system. In the other three boiler rooms are the Dürr boilers, having a working pressure of 220 pounds per square inch. These boilers are arranged to work under a modified system of forced draft, for which purpose there are four fans in each boiler room. The Dürr boilers were made by the Fairfield Company, who are the sole agents for these boilers in this country.

Clio.—The third-class cruiser *Clio*, which is fitted with water-tube boilers of the Niclausse type, has successfully completed her trials, which all proved successful. The results were as follows: Thirty-hours' trial, three-fourteenths maximum I.H.P.: Pressure of steam in boilers, 156 pounds; at engines, 147 pounds; vacuum, 27.1 inches; revolutions, 119.7 per minute; I.H.P., 313; coal consumption, 2.31 pounds per I.H.P. per hour; loss of water, 1.15 tons; speed, 8.7 knots. Thirty-hours' trial at five-sevenths maximum power: Pressure of steam in boilers, 213 pounds; at engines, 196 pounds; vacuum, 26.7 inches; revolutions, 183 per minute; I.H.P., 1,036; coal consumption, 1.95 pounds per I.H.P. per hour; loss of water, 1.58 tons; speed, 13 knots. Full-power trial (eight hours): Pressure of steam in boilers, 221 pounds; at engines, 197 pounds; vacuum, 25 inches; revolutions, 199 per minute; I.H.P., 1,433 (33 in excess of the specification); coal consumption, 2.03 pounds per I.H.P. per hour; loss of water, .7 ton; speed, 13.33 knots.—"J. R. U. S. I." (See Steam Trials.)

Ettrick.—The torpedo-boat destroyer *Ettrick* has completed a successful full-speed trial of four hours' duration off Tynemouth, which was followed by circle-turning and steering, stopping and starting trials. For the former trial the mean results of six runs on the measured mile were 25.464 knots, 347.4 revolutions per minute, and 7,173 I.H.P. During the remaining three hours' continuous steaming the speed was determined by the revolutions (348.75) worked out at 25.568 knots, and the horse-power 7,125. The conditions of the contract were 25.25 knots for the first hour and 25.5 for the last three, the I.H.P. not to exceed 7,000 for the latter speed; but a margin of 5 per cent. was allowed on this, and also on the revolutions, viz: 350. The trial was considered satisfactory, and the *Ettrick* will be got ready for her coal-consumption trial at 13 knots for twelve hours, which

will determine her radius of action at her most economical speed. —" J. R. U. S. I." (See Steam Trials.)

Erne.—The destroyer *Erne* has had a satisfactory official four-hours' coal-consumption trial at full speed off Tynemouth. Starting with six runs on the measured mile, the mean speed obtained was 25.374 knots, with 347.5 revolutions per minute, and 7,150 I.H.P. developed by the engines, this being well above the contract speed of 25 knots for the first hour, and also that required for the last three hours, viz: 25¼ knots. So the engines were kept going at about this speed for the remainder of the trial, the figures at the end working out at 25.395 knots, 347.8 revolutions, and 7,160 I.H.P. The steam pressure throughout was about 245 pounds per square inch, and air pressure in the stokeholds 2 inches, the fans making 400 revolutions. The piston-rod glands leaked slightly, but otherwise the machinery worked well. On the coal remaining in the bunkers being weighed out, the consumption for the four hours was found to have been 28½ tons, which, divided by the H.P., worked out at 2.25 pounds per I.H.P. per hour. The figure allowed is 2.5 pounds.—" J. R. U. S. I." (See Steam Trials.)

Flora.—The second-class cruiser *Flora*, while on her way from Comax (B. C.), where she had been coaling, to Esquimalt, went on shore off Village Point, Denman Island. There was a dense fog at the time, and the vessel passed on the wrong side of one of the beacons and went on the rocks. Although hung up in a dangerous position, all her fore part being out of the water at low tide, and her stern submerged, she was successfully floated, after the removal of her coal and stores, and has been towed to Esquimalt for docking. She does not appear to have received much damage, and made very little water after she was floated.

Floating Coal Depot.—Messrs. Swan & Hunter and Wigham Richardson recently launched from their shipbuilding yard at Wallsend, on the Tyne, a large floating coal depot for the British Navy. The depot is intended to provide a method of storing large quantities of coal afloat under the most favorable conditions for rapidly filling it into bags without shoveling, and for discharging it into war vessels by means of transporters driven by

electric motive power. The depot is of 12,000 tons storage capacity—11,000 tons in hoppers and 1,000 tons in bags—and is equipped with twelve Temperley transporters entirely operated by electric machinery, and the hoppers are fitted with eighty coal chutes for filling the bags without shoveling.

FRANCE.

The new construction in the French Navy is somewhat retarded by various circumstances in connection with the building program.

The large ships which have been placed in active service during the past year are: Battleship, *Henri IV;* armored cruisers, *Jeanne d'Arc, Marseillaise, Gueydon* and *Dupleix;* protected cruiser, *Jurien de la Gravière.*

Trials in progress or finished but not yet entered in service: Battleship *Suffren*, 17.9 knots; armored cruisers, *Sully, Desaix* and *Klèber*, 21 knots, *Admiral Aube*, 21.9 knots, and the *Gloire* and *Condé.*

There still remain, of large vessels under construction and authorized, and not included above:

Battleships (of 14,865 tons): *Démocratie, République, Patrie, Jules Ferry, Liberté, Vérité, Justice.*

Armored cruisers: *Victor Hugo, Jules Michelet, Ernest-Renan. Dupetit Thouars* (*Montcalm* type), *Léon Gambetta.*

Two battleships of the program of 1900 have been launched, *Patrie* and *Jules Ferry.*

République.—The battleship *République*, which was laid down at Brest on December 2, 1901, and launched on September 4, 1902, ought, according to the provisions of this year's Budget, to be ready for her trials on October 1, 1904; it is probable, however, that she will not be ready until the summer of 1906. The *République* is the first of six battleships of 14,865 tons of the programme of 1900. She and the *Patrie* will differ in armament from the other four vessels in carrying eighteen 6.5-inch guns, whereas the others will carry ten 7.5-inch and eight 3.9-inch guns.

Démocratie.—The number of workmen on the battleship *Dém-*

ocratie, at Brest, has been increased in order to insure her being launched before next February, the original time appointed.

Léon Gambetta. — The cruiser *Léon Gambetta*, (Armored cruiser, first class.—EDITOR), of 12,600 tons displacement, is expected to receive a crew shortly for her preliminary trials. She was laid down on January 15, 1901, launched on October 26, the same year, and should have been ready for her trials on October 1 this year, and to be commissioned on May 1, 1904. Her draught of 26.9 feet is considered to be excessive, but it is hoped that she will exceed her contract speed of 22 knots so as to approach more nearly the 24 knots of the English cruiser *Drake*.

Kléber.—The cruiser *Kléber* (Armored cruiser, first class.—EDITOR), made her official trials, at full speed, on October 15 at Cherbourg. Her engines developed 17,370 I.H.P., against the 17,100 contracted for. Her coal consumption was 35.39 pounds per square foot of grating per hour. Her speed is not given. She is fitted with Niclausse boilers.—"Times," London.

While the *Kléber* was running a trial at 14,000 I.H.P., at 19 knots, she came in collision with the submarine *Algérien*, which was only discovered across her bows when it was too late to avoid her. Although the submarine at once dived, she was struck by the cruiser's screws; her rail was smashed and some of the plates on her upper side bent in, but she was able to return to the repairing dock without assistance, which speaks well for the strength of her hull. The *Kléber* had her screw shafts damaged and has had to be docked for repairs.

Mousqueton.—The French torpedo boat *Mousqueton* during her recent trials at Toulon made 29.8 knots, and everything proceeded satisfactorily, including the testing of her 1.85-inch guns and the discharging of torpedoes, until a blade of her propeller broke. She has gone into dock to have a new propeller fitted, an operation which will take eight days.

Marseillaise.—The armored cruiser *Marseillaise*, which made her official trials at full speed on August 4, and has since been in dock to have her engines overhauled, has now undergone further trials. On October 15 her engines developed 11,085 H.P., the revolutions being 111.6, and the speed 18.5 knots. The coal

consumption was 38.077 pounds per square foot of grating per hour. On October 17, with six boilers and the two lateral engines at work, the latter developed 1,839 H.P., the speed being 9 knots; and with six boilers and three engines the results were 2,264 H.P. and 10.5 knots. On October 20 twelve boilers and three engines produced 4,374 H.P., 82 revolutions and a speed of 13 knots; the coal consumption being 13.44 pounds per square foot of grating per hour. With sixteen boilers and three engines the results were 6,937 H.P., 100 revolutions; speed, 16.5 knots; coal consumption, 15.68 pounds per square foot of grating per hour. The object of the trials, in addition to testing the working of the engines, was to obtain a curve of the rates of coal consumption at different speeds. The trials were considered satisfactory. The *Marseillaise* will take the place of the *Dupuy de Lôme* in the Northern Squadron. "Times," London.

Depuy De Lôme.—Extensive repairs are to be taken in hand for this vessel after a long service. From the beginning her boilers were defective because of over forcing during her trials, to reach the expected 20 knots, which she did very nearly (19.7). In actual service, although she sometimes made good speed for long distances at about 17 knots, she could never equal her trial speed, and forcing was avoided because of the weakness of her boiler furnaces, her boilers being of the locomotive type with Fox corrugated furnaces.

New boilers will be given to her of the Normand small-tube type, which will result in a considerable decrease in weight, about 700 tons, of which, owing to too deep draught, a portion will be employed to regain her normal water line, and the other portion, about 300 tons, will be given to increase of coal capacity. Before her overhauling, she carried already 1,200 tons of coal, and upon that amount it is stated that she could travel from Brest to Yokohama at 12 knots. The new boilers will be of the Normand-Sigaudy type, eighteen in number. It is expected that 21 knots will be obtained after the new boilers are installed.—"Le Yacht."

Admiral Aube.—This armored cruiser has just terminated her trials at Cherbourg with a full-power run which gave re-

markable results. Twenty-five hundred indicated horsepower were expected under full-power conditions, all boilers, burning 34.85 pounds of coal per square foot of grate, closed fire rooms and blowers running at full pressure. No speed conditions were imposed, but 21 knots were expected. Penalties were provided, 200 francs per I.H.P. less than 20,500; 1,000 francs per kilogram of coal burned over 170, and non-acceptance at discretion if more than 185 kilograms coal were burned, or if the power fell below 18,000 I.H.P. The results surpassed expectations, and placed the *Admiral Aube* in the first rank of cruisers of her type. The indicated horsepower developed was 22,155. Coal consumption 1.826 pounds per horsepower per hour, and 33.825 pounds per square foot of grate. The trial lasted three hours off Cherbourg, and left nothing to be desired.—"Le Yacht."

At the official coal-consumption trial at 14,000 H.P., the engines actually developed 14,319 I.H.P.; the consumption per H.P. per hour was only 580 gr. (1.16 pounds), the contract allowing for a consumption of from 750 gr. (1.5 pounds) to 800 gr. (1.6 pounds), the consumption per square meter of grate surface being 76 kg. (167.5 pounds) per hour. The speed attained was not given. At a further trial of twenty-four hours the engines developed 10,850 I.H.P., with the very low consumption of 588 gr. (1.17 pounds) per H.P. per hour. Her boilers are of the Belleville type, with economizers.

Victor Hugo.—Armored cruiser, first-class. Work is being pushed forward on this vessel with the expectation of launching her in March. A part of her machinery has arrived from the Indret Foundry, and she will be launched with her boilers and part of her main machinery in place.

Desaix.—The first-class armored cruiser *Desaix* is continuing her trials satisfactorily. At a six-hours' coal-consumption trial, with the engines developing 13,671 I.H.P., and making 136 revolutions, the speed obtained was 19.6 knots, the consumption per I.H.P. per hour being 738 gr. (1.62 pounds) and 102 kg. per square meter of grate surface (20.9 pounds per square foot). She concluded her official trials by a four-hours' run at full speed, at which the engines developed 17,715 I.H.P., being 615 I.H.P.

over the contract, giving a speed of 20.7 knots, which is slightly below the estimated speed of 21 knots. The consumption per H.P. per hour was 838 gr. (1.84 pounds) and 148 kg. per square meter of grate surface (30.34 pounds per square foot). The Belleville boilers with economisers worked well, and it is believed that, with different screws, the contract speed will be reached. It is complained that the stokeholds of all the cruisers of this type are so cramped that the men cannot stand upright in them.

Jeanne d'Arc.—The first-class armored cruiser *Jeanne d'Arc*, which only commissioned some three months ago as the flagship of the Cruiser-Division of the Northern Squadron, is to be temporarily paid off, as she has developed so many defects that it will take five months to make them good.

Jules Michelet.—The first-class armored cruiser *Jules Michelet*, which will shortly be commenced, is to have the Du Temple-Guyot small-tube water-tube boilers, which have not given at all satisfactory results in the *Jeanne d'Arc* and *Jurien de la Gravière*. The Minister of Marine has invited the Indret firm to propose some modifications, which will reduce the excessive expenditure of coal, and it is proposed to increase the grate surface, which, it is hoped, will reduce the consumption from 218 kg. to 187 kg. per square meter of surface (44.7 pounds to 38.33 pounds per square foot). A further modification is now proposed by increasing the grate surface from 118 to 147 square meters (1,270 to 1,482 square feet), which would reduce the coal consumption to 33.3 pounds per square foot of grate surface per hour, while the number of tubes is to be reduced by a twentieth, or a total of 920 tubes.

Suffren.—The first-class battleship *Suffren* is at last approaching the completion of her trials. At a four-hours' full-speed trial the engines developed 16,715 I.H.P., or 500 H.P. over the contract, giving a speed of 18 knots, with a consumption of 149 kg. per square meter of grate surface per hour (30.54 pounds per square foot); her water-tube boilers are of the Niclausse type. She has made some further trials with oil and coal mixed, at speeds varying from 10 to 17 knots, with satisfactory results;

using coal alone, 4,000 I.H.P. was developed, while with the same amount of coal and petroleum 5,900-I.H.P. was developed.

Jurien de la Gravière.—There has been much comment on the failure of the first-class cruiser *Jurien de la Gravière* to realize the expectations which were formed of her, and it is now reported that she is to return from the West Indies on account of defects in her engines. Two frames of her center and one of her starboard engines have cracked, owing to the great vibration of the hull when steaming at only a moderately high rate of speed. The frames in question are rigidly fixed to the inside of the hull, and, the vibrations of the hull and the engines not being in accord, they have been unable to stand the strain. This result was predicted as likely to occur, in a report made by her captain nearly twelve months ago. The cracks in the frames of the central engines are, respectively, 9 inches and 12 inches long, and in that of the starboard engine, 2 inches long.—"J. R. U. S. I."

Patrie.—First-class battleship. This vessel is of the same type as the *République.*

Principal Dimensions.—Length, 440 feet; beam, 79 feet 6 inches; draught, 27 feet 5 inches; displacement, 14,865 tons; I.H.P. designed, 17,475; speed, designed, 18 knots.

Armament.—Four 12-inch guns in turrets; eighteen 6.5-inch guns, twelve in six turrets and six in casemates; twenty-eight smaller guns distributed in tops and superstructure; five torpedo tubes, of which two are submerged.

This vessel is not yet fitted with her machinery and boilers, and the armor is delayed, so that her entry into service can scarcely be expected before the first part of 1907. This armored type of vessel leaves much to be desired, and certain improvements which have been proposed have not been approved. It should suffice for the Minister of Marine to fix the speed, radius of action, number of guns and armament, which would avoid the regretted restrictions upon the builders. The Russians have adopted this plan, and have been well satisfied, insomuch that the *Czarevitch* is actually the most successful battleship of the entire Naval world.

Justice.—As for the *Justice*, she is greatly retarded. Her dis-

placement is the same as that of the *Patrie*, but her secondary battery consists of only ten guns of 7.5 inches, six in simple turrets, arranged as formerly, and four in casemates, those amidships being omitted. Their utility is doubtful, and the arc of fire being small and height above water line insufficient.—"Le Yacht."

Gloire and Condé.—Armored cruisers. These vessels are undergoing their trials. They are sister ships and of the following general dimensions: Length, 458.5 feet; beam, 66.3 feet; draught, 23 feet; displacement, load draught, 10,014 tons; I.H.P., 20,500; speed, designed, 21 knots; triple screw.

Armament.—Two 7.7-inch guns, one forward and one aft; eight 6.5-inch rapid firing; six 4-inch rapid firing; eighteen 47-mm. rapid firing; four 37-mm. rapid firing. Torpedo tubes, five, two submerged.

On December 24 *La Gloire* left the builders' dock for the first official trials.* The midship engine and five boilers of twenty-eight were working. The engine developed 1,914 indicated horsepower, with 80 revolutions per minute, giving her a speed of 9 knots per hour. The coal consumption was 14.75 pounds per square foot of grate surface per hour. The official trial at full power is to follow shortly.

Later notes on the trial of the *Gloire* on January 20th state that she made 21½ knots (elsewhere stated as 21 knots only). Consumption of coal, 1.96 pounds per H.P. per hour, and 34.2 pounds per square foot of grate per hour. On the 23d, with natural draft, and engines developing 14,400 I.H.P., her speed was 19.3 knots; coal consumption, 1.7 pounds per H.P. per hour, and 22.5 pounds per square foot of grate.

On her full-power official trial trip this vessel is said to have developed a maximum speed of 21.2 knots. The coal consumption was 34.65 pounds per square foot grate surface.

The armored cruiser *Condé*, which is the last of five vessels of this type still under construction, recently made consumption

*(The *Gloire* has been under trial for nearly a year, her trials being interrupted by numerous small breakdowns. Her sister ships *Sully* and *Montcalm*, built at private shipyards, seem to have been the only ones of this class to escape these misfortunes.—EDITOR.)

trials, developing 8,000 indicated horsepower during 6 hours. Eighteen thousand indicated horsepower were developed at the full-power trial. During the test one of the middle front boiler tubes exploded, but no one was hurt.

The Minister of Marine on Submarines and Submersibles.—Speaking in the French Chamber on 2d December last, M. Pelletan, Minister of Marine, made the following statement regarding the rival merits of submersibles and submarines:

"There is a difference of opinion between the schools of Toulon and Cherbourg, one affirming the superiority of the submarine, and the other of the submersible type. The difference between the two is that the former when at the surface are almost awash, while the latter have a cartain amount of freeboard, and thus have greater navigability. It is evident that the further a vessel is out of the water the greater is its buoyancy, and the longer the time thus reqired for its submersion. The boats of 400 tons which have been ordered, if they were submersibles, would require 30 per cent. of their displacement, or 120 tons of water, in order to submerge them, but only 6 or 7 per cent., or something less than 30 tons of water, if they are submarines. In my opinion, this not being able to dive quickly and the necessity for letting in a large quantity of water, is one of the great defects of the submersible. It is not to be denied, however, that the submersible has a great hygienic advantage, in the men being able to come on deck, even in a rough sea, and get a breath of fresh air, which it is difficult for them to do in the submarines as at present constructed.

"Future submarines would be provided with a bridge above the deck, where it will be possible for the men to get air, while, at the same time, they will retain the advantage of being more readily and quickly submerged. The chief guarantee that a submarine possesses against destruction is that of being able to disappear quickly, and it is this quality that gives superiority to the submarine proper over the submersible type. This defect in the latter might be remedied to some extent; but it was the reason why M. de Lanessan himself suspended the construction of this class. I consider it necessary to give our submarines greater of-

fensive power by increasing their tonnage, and for this reason, after having carefully studied the question, I have been induced to sanction the building of six submarines of 1,500,000 francs ($291,600) each, and with a displacement of 400 tons."

GERMANY.

A Larger Number of Ships have been launched in 1903 for the German Navy than in any previous year. In 1897 six ships took the water; in 1898, four; in 1899, six; in 1900, seven; in 1901, six; in 1902, five; while the number rose to ten last year, viz.: three first-class battleships, one first-class armored cruiser, three third-class cruisers, one gunboat and two river gunboats. It is noteworthy that the three battleships launched were all built at private yards: The *Elsass* at the Schichau Works, Danzig; the *Freussen* at the Vulcan Yard, Stettin, and the *Hessen* at the Germania Yard, Kiel, which belongs to the great Krupp firm. The *Roon*, the first-class armored cruiser launched, was the only one of the ten which was built at one of the Imperial dockyards, and she was built at Kiel. Two new battleships were laid down during the year, one at the Germania Yard, Kiel, and the other at the Schichau Works, Dantzig; while a new first-class armored cruiser has been laid down at the Imperial Dockyard, Kiel, and two third-class cruisers have also been laid down. The first launches of the ships laid down under last year's estimates will take place early next summer, and will be the two small cruisers "*M*" and *Ersatz Merkur*, which are being built at the Weser Yard, Bremen, and the Vulcan Yard, Stettin, respectively.

Wörth.—The work is proceeding with the first-class battleship *Wörth*, one of the four ships of the *Brandenburg* class, which has been undergoing a partial reconstruction, with the view of bringing her up to date, and is nearly ready for her trials. Her three sister ships, which are also undergoing reconstruction in the same yard, will not be finished for another year or eighteen months. Among other alterations which are being carried out is the substitution of water-tube for the old cylindrical boilers; the removal of all superfluous wood; the fitting of submerged torpedo tubes, and the placing of two additional 4.1-inch guns in the casemated battery.

VESSELS BUILDING.

Name.	Displacement.	Where building.	Remarks.
Battleships.			
Mecklenburg	11,900	Stettin.	Under trial.
Schwaben	11,900	Wilhelmshaven.	Lchd. Aug., 1901; compl. 1903.
Braunschweig	13,200	Kiel.	Lchd.; complete in 1904.
Elsass	13,200	Dantzic.	Lchd. May 26th, 1903.
Preussen	13,200	Stettin.	Lchd. Oct. 31st, 1903. To be completed 1905.
Hessen	13,200	Kiel.	Lchd. Sept. 18th, 1903.
M (*Lothringen*)	13,200	Dantzic.	Building.
N	13,200	Gaarden.	Building.
Armored Cruisers.			
Prinz Heinrich	8,868	Kiel.	Under trial.
Prinz Adalbert	9,050	Kiel.	Under trial.
Prinz Friedrich Karl	9,050	Hamburg.	Lchd. June, 1902.
Roon	9,050	Kiel.	Lchd. June 27th, 1903.
E (*ersatz Deutschland*)	9,050	Hamburg.	Building.
F	9,050	Kiel.	Building.
Protected Cruisers.			
Frauenlob	2,715	Bremen.	Under trial.
Arcona	2,715	Bremen.	Under trial.
Undine	2,715	Kiel.	Lchd. Dec., 1902; compl. 1903.
Hamburg	3,000	Stettin.	Lchd. July 25th, 1903.
Bremen	3,000	Bremen.	Lchd. July 9th, 1903.
Berlin	3,000	Bremen.	Lchd. Sept. 22d, 1903

Undine, Hamburg, Bremen and **Berlin.**—These vessels, with two others almost ready for launching and six others which already have gone into commission, belong to a class of fast cruisers of 20 to 22 knots, ranging from 2,600 to 3,250 tons displacement. They have been built by the German Navy for scout service, and have proved to be a very successful type. They have a length of 361 feet, a breadth of 40 feet 4 inches, and a draught of 15 feet 9 inches, and are propelled by two sets of four-cylinder triple-expansion engines, working two propellers, developing about 8,000 to 10,000 indicated horsepower. They carry a total complement of 259 men. Steam is provided by water-tube boilers of the Niclausse, Thornycroft or Thornycroft-Schulz type, and the normal coal-bunker capacity is between 600 and 700 tons. The protective deck has a thickness of 2 inches made up in three plates, while the armor of the conning tower is $3\frac{1}{8}$ inches thick. The vessels carry a numerous secondary battery, consisting of

ten 4¾-inch rapid-fire guns, ten 1½-inch machine guns and four automatic rifles, and are equipped with two submerged torpedo tubes, located on the sides.—" Nautical Gazette."

Frauenlob, Arcona.—Two of the new third-class cruisers of the *Undine* type, the *Frauenlob* and *Arcona*, have recently successfully completed their trials. They are sister ships of 2,700 tons displacement, and the engines had to develop 8,000 I.H.P., making 165 revolutions per minute, giving a speed of 21 knots. The *Frauenlob* was built at the Weser Yard, Bremen. At her twenty-four-hours' coal-consumption trial, the engines to develope 5,600 I.H.P., 5,579 I.H.P. was actually developed, and making 139.5 revolutions per minute; the consumption being 897 grams (1.79 pounds) per I.H.P. per hour, with an air pressure of 17.5 millimeters (.68 inch). During the ninety-three-hours' endurance trial the engines developed 5,746 I.H.P., making 141.7 revolutions, giving a speed of 19.2 knots. At the six-hours' full-speed trial the engines developed 8,594 I.H.P., making 159.5 revolutions, giving a speed of 21.102 knots, which is slightly above the contract. With the engines developing 1,259 I.H.P., making 83.9 revolutions, the speed was 11.8 knots; with 3,576 I.H.P., and 121.3 revolutions, the speed was 16.68 knots.

The *Arcona* was also built at the Weser Yard, Bremen. At her six-hours, full-speed trial under forced draft the engines developed 8,587 I.H.P., making 163.7 revolutions, with an air pressure of 38.5 millimeters (1.51 inches). At the twenty-four-hours' run, with the engines developing 1,200 I.H.P., the coal consumption was 897 grams (1.794 pounds) per I.H.P. per hour. At the twenty-four-hours' coal-consumption trial at 5,600 I.H.P. the engines developed 5,727 I.H.P., making 145.7 revolutions, with an air pressure of 19 millimeters (.74 inch), and a coal consumption of 895 grams (1.79 pounds). The details of the ninety-three-hours' endurance trial are not given, but the engines and boilers are reported to have worked satisfactorily. The following are the mean results of the principal trials:

Revolutions, .	161.1	148.0	119.25	88
I.H.P., . .	8,291	5,881	3,165	1,318
Speed, . .	21	19.54	15.95	12.04

—" J. R. U. S. I."

Mecklenberg, Schwaben.—The battleships *Mecklenberg* and *Schwaben*, of the *Wittelsbach* (improved *Kaiser*) class, recently went into commission, completing a new class of battleships. They are of 11,800 tons displacement, developing 18 knots per hour, and are propelled by three sets of three-cylinder triple-expansion engines of 14,500 indicated horsepower, working three screws. Steam is provided by six Scotch and six water-tube boilers of the Schultz type. The normal bunker capacity is 650 tons. In addition they have a capacity for 200 tons of oil fuel.

The broadside armor extends from about 4 feet 6 inches below the water line to the upper deck, a depth in all of about 21 feet. It is 8⅞ inches thick. This depth and thickness extends over the whole length of the ship between the turrets. Forward of this there is a continuation of about 4 inches thick to the ram, of water-line plate 8 feet deep, 3.6 above and 4.6 below the load water line. Abaft the after turrets the armor is continued to the stern with a thickness of 4 inches.

The vessels have a length of 393 feet 9 inches, a breadth of 68 feet 3 inches and a draught of 24 feet 6 inches.

The 3-inch armored deck runs down to the bottom of the side armor, which is improvement over the *Kaiser* class.

The citadel has a thickness of about 5½ inches, which is also the thickness of the casemates. The armament consists of four 9.5-inch guns in armored turrets of 9⅞ inches; eighteen 6-inch guns in casemates; twelve 3.5-inch guns in citadel; twelve 1.5-inch machine guns, and eight automatic rifles.

The deck armor over casemate and citadel has a thickness of 1⅝ inches. One armored cross bulkhead divides the casemate into two parts. Every gun mounted in the casemate is separated from the other by protective bulkheads of 1-inch thickness. The conning tower has a 9⅞-inch armor all around and a 5½-inch deck armor.

The ships have two smokestacks and two military masts and are provided with two boat cranes. The total complement is 660 to 680 men. The ships are equipped with six torpedo tubes, five of which are submerged. The armor is prepared and hardened according to Krupp's system.—"Nautical Gazette."

Mecklenburg.—The "Marine Rundschau" gives the following particulars of the trials of the German battleship *Mecklenburg*, which is to take the place of one of the *Kaiser* class in the first German home squadron. The screw pitch is from 18 feet to 21.3 feet, but 20.67 feet was found to be the most favorable, and that pitch was adopted throughout the trials. She has three propellers, the center one having four and the lateral ones three blades. In a six-hours' run under forced draft with 109 revolutions per minute, her engines developed 13,355 I.H.P., the contract being for 110 revolutions and 13,600 H.P. Her actual speed for this run is not given, but her contract speed is 18 knots. The coal consumption was 1.7 pounds per H.P. per hour. In an endurance run of 94½ hours, the engines developed 9,659 I.H.P. against an expected 9,500 I.H.P., the average number of revolutions being 96 per minute and the speed 16.42 knots. The coal consumption measured during 28 of the 94½ hours was at the rate of 1.64 pounds per H.P. per hour. The trial was interrupted after the 94½ hours, in order to take advantage of the deep water in which the ship found herself, and to make a trial run with forced draft, when the speed attained was 18.1 knots. A coal-consumption trial in a run of 24 hours, during which the engines developed 3,188 I.H.P., gave 1.55 pounds per H.P. per hour. After various runs with either one, two or all three engines working, the German Admiralty took over the vessel from her builders, the Vulkan Company at Stettin.—"London Times."

Hamburg.—Considerable interest attaches to the results of the trials of the German protected cruiser *Hamburg*, as she is one of two vessels building by the Vulcan Company of Stettin, for the purpose of testing the relative efficiency of reciprocating and turbine engines. The *Hamburg* has the ordinary piston and crank engines; the sister cruiser, to be fitted with the Parsons rotary engine (*Merkur*, 2,275 tons), is far advanced. Both hulls are exactly alike; the length is 360 feet 10 inches, the beam 40 feet 4 inches, and, at 16 feet 5 inches draught, the displacement is 3,000 tons. Normand boilers are used, and with twin-screw reciprocating engines a speed of 23.3 knots has been realized with 11,000 I.H.P. This power is 1,000 in excess of that an-

ticipated in design, and the result was the addition of 1.3 miles per hour to the speed expected. The turbine boat has therefore a severe task set. It will have exactly the same under-water form and the same boilers, and on trial will have the benefit in reduced displacement of any economy in weight resulting from the application of the turbine system of propulsion. Each ship is to be driven to give its best result, and the weight of water and coal used to attain a given speed over a lengthy run will be the measure of the work done by each system of prime mover. Curiously enough, these German ships are of the same size as the *Amethyst* and *Topaze*, the British cruisers with which similar comparative trials are to be made, the former having the turbine and the latter reciprocating machinery. The length and beam differ only by inches, but the British ship is of lighter draught, and the anticipated speed with 9,800 I.H.P. is 21¾ knots. The British ships have twelve 4-inch guns, the German ships only ten; but the latter have more smaller guns.

The great difference in the two pairs of ships, however, concerns the number of turbines, shafts and propellers, and this is one of the questions which is at present engaging the attention of those responsible for the design of the new Cunarders. All the ships hitherto fitted with turbine machinery in this country have had three shafts; the earlier vessels have two screw propellers on each outboard shaft, with one in the center. Experiments demonstrated that single screws on all three shafts gave higher efficiency—partly, no doubt, because of the proximity of one of the double screws, the forward one, to the hull of the ship. The Germans, however, are adopting four shafts with one propeller on each, an arrangement which will not only prove convenient for utilizing a part of the full available power when cruising at low speeds, but may give higher efficiency. The difficulty with turbines is to attain high economy at reduced power. By working two of the four shafts it will be possible, when low speed is desired, to run the turbines at almost their full power. This, however, is not the question with the Cunard commission; it is purely one of comparative propulsive efficiency at the full speed, and it is to test this question of three or four shafts that the small

experimental vessel is now being equipped on the Tyne. The question of fitting turbines to high speed Atlantic liners is of such magnitude that it is well that every phase should be examined so as to ensure the highest degree of permanent success when the ultimate design has been fixed upon.—"Marine Review."

Preussen.—The battleship *Preussen*, which was launched at the Vulcan yards, Stettin, on October 31, is the vessel previously known as "K," 13,200 tons, and 16,000 horsepower.

Prinz Friedrich Karl, Prinz Adalbert.—The armored cruiser *Prinz Friedrich Karl* has gone to Wilhelmshaven for her trials. She differs but slightly from the *Prinz Heinrich*, and is a sister ship to the *Prinz Adalbert*, which will also be ready for her trials in the near future. These two cruisers have each a displacement of 9,050 tons, engines of 17,000 horsepower, and a speed of 21 knots. Their length is 393.7 feet; beam, 64.3 feet; draught, nearly 24 feet. They each carry four 8.26-inch guns, instead of the two 9.45-inch guns carried by the *Prinz Heinrich;* also ten 6-inch, ten 3.46-inch and ten 1.45-inch guns, and four torpedo tubes. The armor belt and the protection of the casemates with the 6-inch guns are 3.94 inches thick, the protection of the turrets for the 8.26-inch guns is 5.9 inches thick, and the armor deck is 1.97 inches thick.—"London Times."

ITALY.

Italian naval work in progress and contemplated for the current year is as follows: Fitting the cruiser *Francesco Ferruccio*, at Venice; constructing and fitting the battleships *Vittorio Emanuele*, at Cestellamare and Naples; the *Regina Elena*, at Spezia; the *Roma*, at Spezia, and the *Napoli*, at Castellamare and Naples; the beginning of a new battleship, of the *Vittorio Emanuele* class, at Castellamare; the construction and fitting of the submarine *Glauco*, at Venice; the construction and fitting of four other submarines, A, B, C and D (two already commenced); the fitting of the two torpedo-boat destroyers *Zeffiro* and *Espero*, at Pattison's and in the arsenal at Naples; construction and fitting of fourteen first-class torpedo boats, *a* to *n* (eight already commenced), two lake gunboats, and various auxiliary vessels.

The *Roma* and *Napoli*, mentioned above, were laid down last year. The two submarines begun last year are to have a speed of 14 knots on the surface, and a radius of action of 2,000 miles. The *Zeffiro* and *Espero* are each of 330 tons, with engines of 6,000 horsepower, the speed being 30 knots. The *Vittorio Emanuele* and *Regina Elena* were launched last year. The *Francesco Ferruccio* had already begun her trials. It is evident, therefore, that the only new vessels to be laid down during the year 1904–5 are one battleship, of the *Vittorio Emanuele* class (12,625 tons, 19,000 horsepower and 20 knots); two submarines, and six torpedo boats. "Le Yacht" mentions designs of a new battleship of 17,000 tons, and of the laying down in 1903 of a cruiser of the *Puglia* class (3,500 tons, 9,000 horsepower and 20 knots), but no trace of either of these appears in the 1904–5 budget.—"Engineering," London.

Napoli.—The battleship *Napoli*, building at Castellamare, has the following general characteristics: Length over all, 474 feet 6 inches; length on load water line, 435 feet; beam, 73 feet 2 inches; draught, forward, 24 feet 3 inches, aft, 27 feet 3 inches; displacement, 12,625 tons; armament, two 12-inch guns, twelve 8-inch guns, twelve 3-inch guns, 4 torpedo tubes; armor, water line belt, 9⅞ inches, reduced fore and aft, 7⅞ inches; cross armor, 7⅞ inches; deck, protective, 2 inches; turrets, 12-inch guns, 9⅞ inches; shields, 8-inch guns, 5⅞ inches; conning tower, 9⅞ inches; indicated horsepower 20,000; speed, 22 knots.

This vessel will have twenty-two Babcock & Wilcox boilers, having a total of 56,200 square feet of heating surface and 1,600 square feet of grate surface.

JAPAN.

New Battleships.—The contracts for the construction of two battleships for the Japanese Navy are definitely signed. One of these is to be built by Vickers, Sons and Maxim, and the other by W. G. Armstrong, Whitworth and Co. Each vessel will be of 16,400 tons displacement, and will be fitted with machinery to enable a speed of between 18½ and 19 knots to be attained. The armor protection will be arranged on the concentrated-case-

mate system first introduced in the Japanese battleship *Mikasa*, completed in 1902 by the Vickers Company, and since adopted in the eight British battleships of the *King Edward VII* class and in the *Triumph* and *Swiftsure*—the two vessels originally built for the Chilian Navy. The new Japanese ships will be more heavily armed than even the *King Edward VII* class, for, although the number of guns may remain the same, the caliber of several of them will be greater, the weight of shot being increased to 11 tons per minute, as compared with 9 tons in the British ships, so that the new Japanese battleships are the most powerful yet ordered for any navy.—"Engineering," London.

Kasuga and Nisshin, armored cruisers.—The two armored cruisers, *Rivadavia* and *Moreno*, recently completed at the yard of Messrs. Ansaldo Bros., at Genoa, for the Argentine Republic, have been purchased by Japan for the sum of about $7,290,000, and renamed the *Kasuga* and *Nisshin*.

The two ships belong to the *Garibaldi* class, the first of which was laid down for the Italian Government, and bought for Argentina. The second was similarly purchased by the Spanish Navy. The third vessel, also laid down for Italy, was purchased by Argentina. The fourth ,the *Guiseppe Garibaldi*, belongs now to the Italian Navy. Now are the two Argentine ships bought for the Japanese Navy, so that of the six ships only one has been completed for the navy for which she was laid down. Each successive ship marks an improvement in her type and over her predecessor. The dimensions are:

Length (extreme), 108.86 meters (357 feet 2 inches); between perpendiculars, 104.86 meters (344 feet); total width, 18.71 meters (61 feet 10½ inches); depth (molded), 12,19 meters (40 feet); draught, aft, 7.70 meters (25 feet 3 inches); draught, amidship, 7.35 meters (24 feet 1 inch); draught, forward, 7 meters (23 feet); displacement on above draught, 7,750 metric tons (7,632 tons); full power of machinery, 13,500 I.H.P.; designed speed, 20 knots; total coal-carrying capacity, 1,150 tons; radius of action at 10 knots speed, 5,000 nautical miles.

The armor protection was manufactured at the Terni Steel Works, hardened by the latest process. There is a central

armored redoubt, which extends for about half the length of the ship, the belt being 150 millimeters (5.9 inches) thick at the sides, and the athwartship bulkhead plates, 120 millimeters (4.7 inches) thick. Forward and abaft the redoubt there is a belt extending 1½ meters above and below the water line, of a thickness commencing with 150 millimeters (5.9 inches) and diminishing to 80 millimeters (3.1 inches) at the extreme ends. The armored deck over the redoubt is formed of two plates, with a total thickness of 40 millimeters (1.6 inches), and beyond this it is of 20 millimeters thickness.

The armament in the two new ships differs slightly. In one ship there is a single 10-inch gun mounted in the forward barbette, with two 8-inch guns in the aft barbette; while in the other vessel a pair of 8-inch guns are mounted both in the forward and aft barbettes. Otherwise the armament is the same, and includes fourteen 6-inch guns protected by the citadel armor—five on each broadside on the main deck and four mounted on the upper deck at the four corners of the citadel. There are four of these quick-firing guns, to fire both fore and aft in line with the keel. There are also ten 3-inch guns, six 1.85-inch guns, two Maxims and four torpedo-launching tubes in each ship. These tubes are above water and within the armored citadel. There are two main magazines, situated directly under the fore and aft barbettes, and four for the secondary guns—two being in the center of the vessel and one forward and one aft.

The propelling machinery consists of two sets of 3-cylinder triple-expansion engines, and is designed for 13,500 indicated horsepower. It was constructed at the builders' Sampierdarena Works, and is expected to give a maximum speed of 20 knots.

The boilers are cylindrical, four single-ended and four double-ended. At their normal draught these vessels carry 650 tons of coal, but the maximum storage is 1,100 tons.

The electrical plant is considerably more powerful than hitherto fitted in vessels of this class, there being three large dynamos placed forward under the protective deck and two others for general use on the upper deck amidships. The electrical current

is used not only for lighting and searchlight purposes, but for training guns, for night sights, for firing the guns, for ammunition hoists, for driving tools in the workshop, and for speed and direction indicators connected with the main engines.

One of the vessels was launched in October, 1902, and the other in March, 1903.

The *Kasuga* is reported to have made a trial speed of 20.2 knots with 14,900 H.P. on a draught of 24 feet 5 inches, and a displacement of 7,400 tons. The *Nisshin*, later, is reported to have made 20.59 knots on about the same average draught and with 14,800 H.P.

Otowa.—Cruiser launched from the Navy Yard at Yokosuka. The keel was laid January, 1903.

General characteristics: Displacement, 3,000 tons; length, 330 feet 9 inches; breadth, 41 feet 3 inches; draught, 16 feet 4 inches; indicated horsepower, 10,000; boilers, ten Niclausse; speed, 21 knots; armament, two 5.9-inch rapid-fire guns; six 4.7-inch rapid-fire guns; four 3-inch rapid-fire guns; two machine guns.

RUSSIA.

During the Past Year construction has been begun on four Battleships: *Imperator Paul I* and *Andrei Pervozvannei*, in northern yards, 16,500 tons displacement, 18,000 I.H.P. and 18 knots speed; *Erstafi* and *Johann Slatust*, in southern yards, 12,700 tons displacement, 10,600 I.H.P. and 18 knots speed. These four vessels are to be finished in 1906.

One Gunboat, *Khivinetz*, at St. Petersburg, 1,300 tons and 13 knots.

Six Torpedo-Boat Destroyers of 350 tons and 26 knots, at the Neva works.

Three Torpedo-Boat Destroyers at Abo, 230 tons, 30 knots (*Sokol* type).

One Torpedo Transport, *Volga*, at St. Petersburg, 3,300 tons, 7,500 I.H.P., and 19 knots.

Other small vessels, submarines and torpedo craft.

Vessels launched during the year are:

Slava, Armored Cruiser, at Baltic works, 13,550 tons, 16,300 I.H.P., 18 knots, to be ready in 1904.

Kagul, *Oleg*, first-class Protected Cruisers, at Nicolaïeff and St. Petersburg, 6,700 tons, 10,500 I.H.P., 23 knots, to be ready early in 1905.

Almaz, *Izumrud*, *Zemtchug*, at Baltic works and St. Petersburg, Protected Cruisers of 3,100 tons, 17,000 I.H.P., and 24 knots. The *Almaz* is already commissioned and the others are to be ready soon.

Other small vessels.

Trials of vessels during the year are:

Three Battleships, 16,000 tons; *Borodino*, trials in progress; *Imperator Alexander III*, 16,265 I.H.P. and 17.36 knots; and *Kniaz Suvaroff*, trials in progress. One Battleship, 12,500 tons, *Kniaz Potemkin Tavritchesky*, 10,600 I.H.P., 17 knots. Two Protected Cruisers, *Aurora*, 6,730 tons, 12,000 I.H.P., 19 knots, and *Otchakoff*, 6,600 tons, 19,500 I.H.P., and 23 knots, trials in progress.

One Protected Cruiser, *Almaz*, 3,100 tons, 17,000 I.H.P., and 24 knots.

Four Torpedo-Boat Destroyers, six Torpedo Boats and two Transports.

The *General Admiral Butakoff*, Coast Defense Battleship, and the Battleship *Orel* are to be launched in the near future, and the latter to have her trials immediately. The Protected Cruiser *Kagul* is also ready for launching.

Imperator Alexander III.—The Russian battleship *Imperator Alexander III* and the second-class cruiser *Almaz* are finishing their trials at Kronstadt, and will leave for the Far East at the end of the year.

The *Imperator Alexander III*, the completion of which was forced with great speed, made her six-hours' official trials at full power and developed 17.5 knots on 15,800 indicated horsepower

and 114 revolutions per minute at a coal consumption of 2.244 pounds per indicated horsepower per hour.

Johann Slatust.—The keel has been laid for the battleship *Johann Slatust* at Sebastopol. She has the following general characteristics: Displacement, 12,733 tons; length, 388 feet 5 inches; beam, 74 feet; draught, 26 feet 11 inches; speed, 18 knots; armament, four 12-inch, sixteen 6-inch, twenty smaller guns; torpedo tubes, five submerged.

Khivinetz.—The gunboat *Khivinetz*, which is nearly completed, has the following general characteristics: Length, 229 feet; beam, 37 feet; draught, 10 feet 9 inches; displacement, 1,316 tons; boiler system, Belleville; speed, 13 knots; armament, two 4⅝-inch, eight 2⅞-inch guns, four machine guns; complement, 200 men.

Kniaz Potemkin Tavritchesky.—The Russian battleship *Kniaz Potemkin Tavritchesky* has passed her trials in the Black Sea with what is reported to have been complete success. She will join the Black Sea fleet immediately. She was laid down in December, 1897, at Nikolaieff, and has been built throughout, both hull and engines, of Russian material. Her hull only was constructed at the Admiralty Yard. Owing to the lack of water, the *Kniaz Potemkin Tavritchesky* was unable to take her engines on board at Nikolaieff, which port she left in the summer of 1902 for Sevastopol, where her engines, boilers, armament and other equipment have been completed. The following are the principal dimensions of the new battleship: Length, 371 feet; beam, 73 feet; mean draught, 27 feet. Her contract horsepower, which on official trial is stated to have been considerably exceeded, is 10,600, the speed contracted for being 17 knots. Her displacement is 12,480 tons. Her principal armament consists of 12-inch and 6-inch guns, the pieces mostly adopted for the battleships of the Black Sea fleet. Of 12-inch guns she has four, of 6-inch quick-firing guns she has sixteen, and in addition to ten machine guns of small caliber she is equipped with fourteen 75-millimeter quick-firing guns.—"Engineering," Jan. 29, 1904.

Izumrud, protected cruiser.—This vessel, launched at St. Petersburg, and built on the *Novik* type, has the following general

characteristics: Length, 361 feet 9 inches; beam, 40 feet; draught, 16 feet 6 inches; displacement, 3,100 tons; speed, designed, 24 knots; bunker capacity, 510 tons.

When launched, seventeen months after the keel was laid, she carried 80 per cent. of her weights. Her armament will consist of six 4.7-inch and six 1⅞-inch rapid-fire guns, two 1½-inch machine guns, and one 2½-inch boat gun. The vessel has seventeen watertight compartments, double bottom and protective deck, with protected engine-hatch sills. The three four-cylinder triple-expansion engines are designed to develop 17,000 indicated horsepower. Steam is provided by sixteen water-tube boilers of the Yarrow type.

Ossliabya.—Launched 1898. Battleship of the same type as the *Peresviet*. Principal dimensions: Length, 436 feet; beam, 71.5 feet; draught, 27.2 feet; displacement, 12,700 tons; I.H.P., designed, 14,500; speed, designed, 19 knots; armament, four 10-inch guns in two turrets, eleven 6-inch, twenty 3-inch and twenty-eight smaller.

There are three triple-expansion, vertical engines and thirty Belleville boilers in six groups. The normal coal capacity is 1,063 tons, but this can be increased to 2,058 tons, and liquid fuel is also provided for.

Almaz, scout.—Principal dimensions: Length, 384 feet; beam, 42.6 feet; displacement, 3,200 tons; I.H.P., 18,000; estimated speed, 25 knots; triple screw. Protection: armor deck, 2 inches, and cofferdams. Armament, six 4.7-inch guns, one forward and one aft, and four in sponsons, one 3-inch and eight 47-mm., all rapid fire; five torpedo tubes.

This vessel is of a type of which the Italians have two, the *Agordat* and the *Coatit*, of 23 knots only. The Russian type, represented by the *Novik* and the *Almaz*, are of 25 knots, which is a considerable improvement for the purpose intended. They are speedy enough to escape from a larger vessel, except in the case of a very heavy sea, and they might overtake and capture the best of the torpedo-boat destroyers in any weather. Perhaps their best service will be in carrying dispatches and in scouting.

MERCHANT MARINE.

Baltic.—The *Baltic* is the largest, and in many respects the finest, passenger vessel afloat, her great size making it possible to add improvements even beyond the other vessels of this type. The dimensions of the *Baltic* are as follows: Length, 725 feet; breadth, 75 feet; depth, 49 feet; gross tonnage, nearly 24,000; cargo capacity, about 28,000 tons; displacement at load draught, about 40,000 tons.

The *Baltic* will be fitted with engines of Harland & Wolff's quadruple-expansion type, about 13,000 I.H.P., and the speed will be about 16½ to 17 knots. The engines are arranged on the "balance" principle, which practically does away with vibration. The twin engines afford another element of safety to the ship and passengers, and the possibility of danger is reduced to a minimum.

OBITUARY.

JOHN PEMBERTON.

John Pemberton, Passed Assistant Engineer in the Navy, died at his home in East Orange, N. J., 28th September, 1903, of heart failure. Born at Albany, N. Y., June 6, 1836.

The death of John Pemberton closed the career of a man whose mature life saw the stirring times of two wars, in both of which he fulfilled his assigned duty honorably, unselfishly and with that unswerving unity of purpose which was his heritage from his Puritan ancestors. During his boyhood he was prepared by private tutors for the famous Rensselaer Polytechnic College at Troy, from which he later graduated with honors, valedictorian of his class. After his graduation he became an assistant engineer in the Croton Aqueduct Department, New York city, his "shop" service being barely long enough to permit his examination for the Engineer Corps of the Navy. Possessed of a high order of mind and essentially a mathematician, his bent was in applied mechanics.

He entered the Navy as a Third Assistant Engineer, December 8, 1862, and, taking passage in the steamer *Blackstone*, joined the steam sloop of war *Canandaigua* on the blockade within two weeks. He served honorably and was promoted to a Second Assistant Engineer, April 8, 1864, being ordered home in October of the same year.

At that time the course at the Naval Academy had been amplified. It was determined to establish a department of physics and chemistry, and a department of steam engineering, including applied mechanics. The Secretary of the Navy, Mr. Gideon Welles, saw the necessity for this reorganization, which the advances of other powers in the art of war had made apparent to him. So, in his wisdom, he ordered a number of Engineers to duty in the Naval Academy, among whom was John Pemberton,

who reported in November, 1864. Appreciating the services of Engineers, Congress, in an Act approved July 25, 1866, accorded commissions to First and to Second Assistant Engineers in lieu of the warrants they had hitherto held. Pemberton was thus commissioned a Second Assistant, from that date, while serving at the Academy. He served in the capacity of Professor in Applied Mechanics, and also in Physics and Chemistry until June, 1867, when he was detached and given two months leave.

While on duty at the Academy he constructed a very clever device for showing, mechanically, the trajectory of a shot as fired from a gun, which excited much admiration and was the subject of essays in the "Journal of the Franklin Institute" and other scientific periodicals. The projectile could be traced in its flight from the moment it left the miniature gun until it struck the target—a miniature monitor. Pemberton's service at the Academy was notable for his success in gaining the friendship, confidence and attention of the midshipmen because of his pleasing manner and personality.

From the 11th of October, 1867, to the 25th of February, 1869, he served on board the *Powhatan* as a watch Engineer. On the 15th of June, 1869, he was again ordered to the Academy, where he served until June, 1872, when he was ordered to the *Tallapoosa*, where he remained until April, 1873, when he was again ordered to the Academy, and promoted to First Assistant Engineer May 17, 1873. Detached from the Academy July 17, 1874, the steam sloop *Plymouth* was his next detail, where he remained until October, 1875, when he was detached and granted sick leave. From mental strain and the ensuing loss of sleep his health had become impaired. He served at League Island Navy Yard from February, 1876, to January, 1878. From August, 1878, to October, 1881, he served on board the Coast Survey steamers *Gedney* and *Blake*, where, in addition to his duties as Chief Engineer, his knowledge of mathematics and his admirable ability as a draftsman greatly increasing the value of his services.

From October, 1881, to September, 1882, he served as Secretary to the Board of Examiners, and was then (1882) ordered to the *Kearsarge*, where he served until May, 1883, when he was

invalided home and placed on sick leave. April, 1884, he was assigned to recruiting duty in Philadelphia, remaining there a year, thence being ordered to the screw sloop *Omaha*, from which vessel he was detached in August, 1885, and again invalided home. He served on board the *Monocacy* from June, 1886, to September, 1889. On the 18th of July, 1887, while attached to the *Monocacy*, he was ordered to Yokohama to assist the famous astronomer, Prof. Todd, in his observation of the solar eclipse, which occurred on the 19th of August, 1887.

He served as inspector of machinery at Philadelphia from December, 1889, to January, 1890, when he was ordered to duty as Professor of Dynamic Engineering at the Pennsylvania State College, at Bellefonte, Pa., and was retired for physical disability on the 14th of September, 1891, on the eve of his promotion to Chief Engineer.

During the war with Spain, 1898, he was put on inspection duty at Philadelphia, being relieved in January, 1899.

The life of John Pemberton was a beautiful one, of extended and honorable service for his country, of brave struggles against physical suffering, of fostering the ties of family and friendship. Death came to him peacefully and without warning September 28, 1903, at East Orange, N. J. He is survived by one daughter, Mrs. Harvey B. McLean.

JEREMIAH M. ALLEN.

On December 28 Jeremiah M. Allen died at his home in Hartford, Conn. For thirty-three years he had been president of the Hartford Steam Boiler Inspection and Insurace Company, during which time he had devoted himself with untiring energy to his chosen work.

There is hardly an institution, financial or industrial, of the city of Hartford with which he has not been directly or indirectly connected. Mr. Allen was a member of many scientific societies, among them the American Society of Naval Engineers, the American Society of Mechanical Engineers, the American Association for the Advancement of Science, the American Historical Society and the Connecticut Historical Society.

For a number of years he was a lecturer at Sibley College, Cornell University, and at the Worcester Polytechnic Institute, and was to deliver a course of lectures at Yale during the present year.

Mr. Allen was born on May 18, 1833, in Enfield, Conn. He was a descendant of Samuel Allen, who settled in Cambridge, Mass., in 1632, and who was an ancestor of Ethan Allen, of Revolutionary fame. The history of the Allen family has been the history of men who have had a bent for mechanics and science. One of the earlier Allens was the first man in the country to make telescopes and microscopes; another was an astronomer.

As a business man, Mr. Allen's abilities were amply shown in the wonderful development of the company under his presidency.

In 1867 Mr. Allen began the publication of "The Locomotive," a journal intended primarily to explain in detail the causes and character of specific boiler explosions, but which was afterwards enlarged in scope so that it now treats also of many matters of current technical and scientific interest.

CLARK FISHER, EX-CHIEF ENGINEER, U. S. N.

Died, on the 31st of December, 1903, Clark Fisher, ex-Chief Engineer, U. S. N.

Clark Fisher was born in Newport, Maine, 69 years before his death. When he was a child of twelve, his father moved to Trenton, New Jersey, where he established a manufactory of anvils of a very superior kind, and made a respectable fortune. In his father's establishment, and in other iron works, the younger Fisher acquired a thorough practical knowledge of machinery in its various applications. In 1859, Clark Fisher entered the "Corps of United States Naval Engineers," very much against the wishes of his father, who wished his son to remain with him and become identified with the lucrative business he had established; and, yielding to the earnest solicitations of his father, he finally resigned in 1872, and entered into the business, conducting it with great energy and skill.

His naval career covered only thirteen years, but in that time he rose from the lowest to the highest grade in his corps, that of Chief Engineer, to which grade he was promoted in 1871. Clark Fisher was a born engineer, with an intense and absorbing love of his profession and a remarkable degree of skill in its practice; his knowledge was deep and original, the product of thought and application as well as of extensive study. It was the greatest disappointment to him to abandon the profession to which he was devoted, and nothing but a sense of duty in obeying his father's wishes would have induced him to do it. He had already achieved distinction in his chosen career, and undoubtedly would have attained its highest pinnacle. He was scientifically well educated and could make a facile and effective speech, while his character was one of lofty standards without a little or a mean trait. At all times, and under all circumstances, his virility, his distinguishing characteristic, came promptly into action and showed the world that he was pre-eminently, and at all points, a man in the highest definition of the word. He had great independence of thought and action, being influenced in no way by either power or position, and never failed to bear himself with the courage of his convictions, whatever or whoever might be opposed, without the slightest regard to personal consequences. If he had a fault in this respect, it was in carrying too far his self-assertion and sincerity; but this fault, if it be one, must be condoned in consideration of its rarity. Courage, self-respect, and the higher qualities of manhood, are not so common that the world cannot pardon their very infrequent appearance.

Clark Fisher had a fine presence and a highly developed physique of great strength and endurance. He had an admirable power for organizing and leading men, and whatever he undertook, he executed with his whole heart, mind, soul and body, sparing neither himself nor others.

He served throughout the civil war, and while attached to the U. S. S. *Iroquois* was a messmate of George Dewey, then a Lieutenant, now the Admiral of the Navy. During an engagement Fisher was captured by the Confederates at Magnolia Station,

but promptly escaped. During several years he conducted the Experimental Station at the New York Navy Yard, under the Bureau of Steam Engineering, Navy Department. The incumbent Chief of Bureau had obtained from Congress an appropriation of $5,000 to test practically the various devices that had been proposed for the combustion of petroleum in the furnaces of steam boilers, and he selected Clark Fisher as the most competent person in his command to make the experiments on a large boiler. A great variety of plans were thoroughly tested, their promoters being freely assisted by the earnest and disinterested coöperation of Mr. Fisher. And so thorough were the trials made by him that nothing has been added since to the subject, nor are there likely to be additions, in the opinion of the writer. The suggestions made by Mr. Fisher carried the experiments far beyond the limit of the original invention. This series of experiments was, perhaps, the most extended and varied ever made on boilers, and in them he developed all the resources of the practical engineer combined with the scientist, a combination which made him especially valuable to his corps.

After resigning from the Navy, Mr. Fisher devoted much time to study and to travel in foreign lands. His thirst for knowledge was insatiable and increased with age and affluence. Returning from abroad two years ago, he fell on board ship and fractured a knee, which injury was followed by complications which eventually undermined his health. He died at his home, Whitehall, Whitestone Avenue, Flushing, Long Island.

NOTICE.

The following self-explanatory invitation has been received, which is published for the information of members, and for which the Council, in behalf of the Society, extends its thanks.

ROBERT MOORE, M. Am. Soc. C. E., Chairman.

H. J. PFEIFER, Assoc. M. Am. Soc. C. E., Laclede Building. Secretary.

AMERICAN SOCIETY OF CIVIL ENGINEERS,

Committee on Universal Exposition, St. Louis, 1904.

Committee.

ROBERT MOORE, M. Am. Soc. C. E., Consulting Engineer and Past President, Am. Soc. C. E., St. Louis, Mo.

EDWARD C. CARTER, M. Am. Soc. C. E., Chief Engineer, Chicago & N. W. Ry., Chicago, Ill.

MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Rear Admiral, U. S. Navy, Washington, D. C.

JAMES L. FRAZIER, M. Am. Soc. C. E., Gen'l Supt. Toledo, St. Louis & W. R. R., Frankfort, Ind.

Committee.

WILLIAM JACKSON, M. Am. Soc. C. E., City Engineer, Boston, Mass. Boston, Mass.

EMIL KUICHLING, M. Am. Soc. C. E., Consulting Engineer, New York, N. Y.

JOHN F. WALLACE, M. Am. Soc. C. E., General Manager, Illinois Central R. R. and Past President Am. Soc. C. E., Chicago, Ill.

ST. LOUIS, MO., U. S. A., *August 22, 1903.*

To the American Society of Naval Engineers,
Washington, D. C.

The American Society of Civil Engineers has appointed the above-named committee to represent it at the Universal Exposition to be held at St. Louis in 1904, to commemorate the Louisiana Purchase.

It is the purpose of the committee to collect and present an exhibit of plans, photographs, models and descriptions of American engineering works, principally work designed by members of the American Society, which it is believed will be of great interest both to laymen and engineers. It is intended also to make the headquarters of the Society, which will be in the Liberal Arts Building, a center of information as to other exhibits

in the Exposition which may be of engineering interest. There will also be a register which will help one to find and meet his friends, and it is hoped that the headquarters may serve as a rallying point and rendezvous for all visiting engineers.

The members of the American Society of Naval Engineers are cordially invited to avail themselves of the conveniences to be provided by our Society during their visit to St. Louis and the Exposition, and it is hoped that a large proportion of them will be able to do so.

By order of the committee.

H. J. PFEIFER,
Secretary.

BOOK REVIEWS.

NAVAL BOILERS, a textbook for the instruction of Midshipmen at the United States Naval Academy, by F. C. BIEG, Lieutenant Commander, United States Navy.

A most excellent and up-to-date compilation of marine boilers, principally in use in the United States Navy; written in an attractive style, giving accurate descriptions of the numerous boilers now in use, their principal points of difference, with reasons and explanations for the changes and designs, the whole idea being a practical foundation upon which the Midshipmen can build up a further theoretical course in designing and calculating problems connected with marine boilers.

Chapter X, relating to steam pipes, fittings, valves, traps, whistles, &c., is very good, giving cuts and explanations of the latest popular types in use.

Chapter XII relates to the details of construction and laying off of plates, &c., in connection with shell boilers, and is most excellent, particular attention being paid to the top-curved head and sheets of our modern double-ended boilers.

ASSOCIATION NOTES.

The annual meeting of the Society for the election of officers for the ensuing year, and for the presentation of the Annual Report of the Secretary-Treasurer, was held at the Bureau of Steam Engineering, Navy Department, Washington, D. C., December 26, 1903.

The election of officers resulted as follows:

President, Rear Admiral John D. Ford, U. S. N. (retired).

Secretary-Treasurer, Lieutenant Milton E. Reed, U. S. N.

Council, Commander Alfred B. Canaga, U. S. N.; Lieutenant Commander Franklin J. Schell, U. S. N.; Lieutenant Commander Emil Theiss, U. S. N.

The following financial statement was submitted by the Secretary-Treasurer:

Balance in bank January 1, 1903	$5,763.39
RECEIPTS.	
From members, associates and subscribers	$3,469.40
Advertising	1,830.12
Sales of JOURNALS and reprints	547.02
Sale of electros	50.18
Interest	103.48
	$6,000.20
Balance on hand January 1, 1903	5,763.39
Total	$11,763.59

EXPENDITURES.

R. Beresford, printing JOURNAL, reprints, etc	$4,092.63
Maurice Joyce Engraving Co	568.52
Annual prize and gold medal	105.00
Purchase of JOURNALS	29.91
B. F. Stevens and Brown	15.00
Import duty on electros	7.25
Advertising commissions paid by check	20.64
Dues returned	5.00
A. H. Raynal	5.00
Incidentals—postage, expressage, telegrams, administering oaths, car fare, etc	77.77
Salary Secretary-Treasurer	900.00
	$5,826.72
Balance on hand January 1, 1904	5,936.87
Net gain for year	173.48

The Council audited the accounts of the Secretary-Treasurer and found them correct.

JOHN R. EDWARDS, *Commander, U. S. N.,*
Secretary-Treasurer.

W. M. PARKS, *Lieutenant Commander, U. S. N.,*
President.

PRIZE ESSAY.

At a special meeting of the American Society of Naval Engineers, held at the Navy Department, Saturday, March 5, 1904, the votes of the members for the Prize Essay were opened and counted.

The gold medal and prize of the Society for the most important contribution to the JOURNAL during the year was awarded to Lieutenant Commander C. W. Dyson, U. S. N., for the article "Screw Propellers of U. S. Naval Vessels."